Research and Application of Flood Regulation System Based on Visual Studio

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Abstract. Due to the characteristics a pumped storage power station owns, the issues it considers concerning flood regulation calculation differ from those of a regular hydropower station. Take the flood regulation system of Hongs pumped storage hydropower station as a study case, the business requirements of flood regulation for regular hydropower station reservoir and pumped storage hydropower station is analyzed. Based on Visual Studio development platform, design systematic functional structures, elaborate the design ideas of core function modules in system development, such as database management, flood regulation principles and information inquiry, etc. Finally introduce the application of the system on flood regulation in Hongs pumped storage hydropower station reservoir.

1. Introduction
With the rapid development of national economy, electric network load and valley-to-peak gap has increased constantly in recent years. Especially with the rapid development of new energy industry like wind electricity, solar energy, etc., the demands on peak cutting, valley filling, energy storage, safe and stable running of electric network are becoming more urgent. Currently, China has introduced a series of policies to encourage developing pumped storage power station. It can be predicted that, in the coming few years, China will unfold a fast-developing stage of pumped storage power station, and need to design and build a large number of pumped storage power stations². Although there is no essential difference of calculation methods on flood regulation between a pumped storage hydropower station and a regular one, due to the characteristics a pumped storage power station owns, the issues it considers concerning flood regulation calculation differ from those of a regular hydropower station. The water-collecting area of a pumped storage hydropower station lower storage reservoir is usually smaller, and the size of its installed capacity is generally larger. Power discharge accounts for large proportion of flood discharge, unable to be neglected. In the calculation of lower storage reservoir flood regulation in a pumped storage hydropower station, the overlays of reservoir inflow flood and power discharge must be taken into account.

As the lower storage reservoir of Hongs pumped storage hydropower station—Hongs hydropower station possesses daily regulating ability, and it is also the lower storage reservoir of Bais pumped storage hydropower station, its flood originates mainly from flood discharge of Bais reservoir and the interval zone between Bais and Hongs. Thus, based on the analysis of joint regulation of Bais and Fengm reservoir, take the overlaid outflow from both Bais reservoir and Bais-Hongs interzone as inflow flood process of Hongs reservoir, meanwhile, in line with norms and requirements, increase the most unfavorable effects caused simultaneously by maximum power discharge and maximum inflow flood peak of Hongs pumped storage hydropower station, take the worst flood regulation result as the characteristic water level for flood control of pumped storage hydropower station lower storage reservoir.
This article takes design and development of flood regulation system in Hongs pumped storage hydropower station as a study case, analyze the design ideas of flood regulation system, and research in detail and introduce the key technologies in system development, providing conducive references to the design and development of other reservoir flood regulation systems\textsuperscript{2}\textsuperscript{3}.

2. System Requirement Analysis

The flood regulation systems in different reservoir not only undertake the common tasks, also the different tasks according to the conditions in different basins such as underlayer characteristics, basin runoff yielding, concentration of channels, etc. Therefore, we can divide the mission requirements of flood regulation system into ordinary mission requirements and regional special requirements.

2.1. Ordinary Mission Requirements

Generally, the major mission of flood regulation system is, in the condition that the type and size of flood discharge structure have been fixed according to inflow flood, proceed storage-discharge regulation calculation based on flood control standard, safety discharge and other flood control measurements of different flood control objects, rationally confirm and design flood control mission, flood control capacity and flood control high water level that should be undertaken by comparison.

2.2. Regional Special Requirements

Generally, flood regulation in different reservoirs has regional special mission requirements. Take the flood regulation system of Hongs pumped storage hydropower station as an example, it uses Hongs reservoir as lower storage reservoir, its flood regulation calculation of should consider about the regulating effect of upstream Bais Reservoir. In addition, Bais reservoir and Fengm reservoir jointly undertake downstream flood control mission, and the flood regulating methods of Fengm reservoir affect the flood regulation of Hongs reservoir. It is necessary to take the overlaid outflow from both Bais reservoir and Bais-Hongs interzone as inflow flood process of Hongs reservoir, based on the analysis of joint regulation of Bais and Fengm reservoir, meanwhile increase the most unfavorable effects caused simultaneously by maximum power discharge and maximum inflow flood peak of Hongs pumped storage hydropower station, and take the worst flood regulation result as the characteristic water level for flood control of pumped storage hydropower station lower storage reservoir.

3. System Framework Design

Reservoir flood regulation system is a dedicated business software system, with specific and less user groups. Considering network safety and convenience of maintenance, choose Visual Studio 2008 as development environment and adopt C/S mode, Microsoft Office Access to develop database, operating platform Windows XP and above\textsuperscript{4}\textsuperscript{5}\textsuperscript{6}. This system takes database as its core, and proceed information inquiry, flood regulation and database management through human-computer interaction interface. See system framework diagram at Figure 1.

![Figure 1. System Framework Diagram](image-url)
4. System Function Development
Flood regulation system contains multiple functional modules such as database management, flood regulation, information inquiry, system maintenance, etc. This article gives introduction of three major function modules-- database management, flood regulation calculation and information inquiry.

4.1. Database Management
In order to comprehensively, accurately and timely obtain necessary information from massive data, reduce data redundancy to the utmost extent and keep data uniqueness and consistency, system divides the data into measured data, auxiliary data and flood regulation calculation result data, and design corresponding database table structure to proceed management[7].

Database management module is responsible to organize the data based on the information provided by database, extract relative data from measured database, auxiliary database and calculation result database to be used by models, at the same time, the result of models goes to resulting database. See system database management structure at Figure 2, the structure has excellent expandability to data and models, and makes the whole system an organic integrity.

![Figure 2. System Database Management](image)

4.2. Flood Regulation Calculation
Take Hongs reservoir as an independent calculating unit. Based on the analysis of joint regulation of Bais and Fengm reservoir, take the overlaid outflow from both Bais reservoir and Bais-Hongs interzone as inflow flood process of Hongs reservoir, meanwhile, in line with norms and requirements, increase the most unfavorable effects caused simultaneously by maximum power discharge and maximum inflow flood peak of Hongs pumped storage hydropower station, take the worst flood regulation result as the characteristic water level for flood control of pumped storage hydropower station lower storage reservoir.
Combined Flood Regulation of Bais-Fengm Reservoir

Based on the analysis of the joint regulation calculation of Bais and Fengm Reservoirs, the inflow flood process of Hongs Reservoir is taken as the superposition of Bais Reservoir outflow and Bai-hong interval flow.

**Figure 3. Flood Regulation Flow Diagram**

Flood regulation calculation of Bais reservoir: Conduct double check under the flood regulation principles regulated in *Joint flood Regulation Scheme of Bais and Fengm reservoir* (hereinafter referred to as Joint Regulation Scheme) approved as ‘State Flood [2004] No.8’, and finally adopt the result comparatively safe to the project. Units participate in flood discharge on the standard of 1200m$^3$/s.

The downstream of Hongs reservoir is backwater end of Fengm reservoir, both sides of the channel have no requirements on flood control. And Hongs reservoir as very small storage capacity, unable to undertake or alleviate the flood control mission undertaken by Fengm reservoir. Reservoir flood control regulation mainly guarantee the safety of reservoir pivot itself. Units participate in flood discharge on the standard of 750m$^3$/s.

Formed by Bais-Hongs interzone flood as primary and corresponding inflow flood from upstream of Bais reservoir, flood period is 3 hours. Initial regulated water level is calculated according to 290m and 291m representatively, and check out system performance. See calculation result of flood control from below Table 1-3. Table 4 sees the outcome table of flood control in *Review Reports on the Pivotal Project of Recovering Reserved Reservoir Capacity in Hongs Hydropower Station* [5].

**Table 1. Statistical Table of Calculation Results**

| project | 0.1% | 1% | Notes |
|---------|------|----|-------|
| 1. initial regulated water level | 290 | 291 | 290 | 291 | Initial regulated water level |
| 2. max inflow (m$^3$/s) | 11940 | 11940 | 8170 | 8170 | approximate rounding |
| 3. max flood stage (m) | 294.6 | 294.6 | 290.9 | 291.1 | |
| 4. max outflow (m$^3$/s) | 11450 | 11510 | 7868 | 8048 | Total reservoir capacity: 2.41×10$^8$m$^3$ |
| 5. corresponding tailwater level | 274.63 | 274.66 | 272.57 | 272.69 | |
### Table 2. Statistical Table of Flood flow regulating Process (initial regulated water level 290m)

| Time  | BaiShan inlow | BaiShan outflow | BaiShan -Hongs Interzone | Hongs inlow | Hongs outflow | BaiS inlow | BaiS outflow | BaiS -Hongs Interzone | P=0.1% |
|-------|---------------|-----------------|--------------------------|-------------|---------------|------------|-------------|------------------------|-------|
| 8.23.4 | 1270          | 1270            | 371                      | 1641        | 1641          | 1170       | 1170        | 267                    | 1437  |
| 8.24.1 | 2180          | 2180            | 410                      | 2590        | 2590          | 2010       | 2010        | 295                    | 2305  |
| 8.25.1 | 3090          | 2500            | 468                      | 2968        | 2968          | 2840       | 2500        | 337                    | 2837  |
| 8.26.1 | 6070          | 2500            | 580                      | 3080        | 3080          | 4750       | 2500        | 417                    | 2917  |
| 8.27.1 | 9050          | 2500            | 1090                     | 3590        | 3590          | 6660       | 2500        | 786                    | 3286  |
| 8.28.1 | 14700         | 2500            | 1770                     | 4270        | 4270          | 10100      | 2500        | 1270                   | 3770  |
| 8.29.1 | 20300         | 2500            | 2300                     | 4800        | 4800          | 13600      | 2500        | 1660                   | 4160  |
| 8.30.1 | 18000         | 6655            | 3450                     | 10105       | 7176          | 12600      | 2500        | 2110                   | 4610  |
| 8.31.1 | 15800         | 9375            | 2180                     | 11555       | 9065          | 11700      | 3835        | 1570                   | 5405  |
| 8.32.1 | 14000         | 10398           | 1540                     | 11938       | 10539         | 10505      | 7065        | 1100                   | 8165  |
| 8.33.1 | 12100         | 10525           | 1140                     | 11665       | 11273         | 9240       | 7193        | 820                    | 8013  |
| 8.34.1 | 10900         | 10573           | 971                      | 11544       | 11467         | 8280       | 7265        | 700                    | 7965  |
| 8.35.1 | 9680          | 10559           | 803                      | 11362       | 11362         | 7320       | 7290        | 578                    | 7868  |
| 8.36.1 | 9080          | 10502           | 671                      | 11173       | 11173         | 6790       | 7279        | 482                    | 7761  |
| 8.37.1 | 8480          | 10419           | 559                      | 10978       | 10978         | 6260       | 7244        | 402                    | 7646  |
| 8.38.1 | 8020          | 9285            | 539                      | 9824        | 9824          | 5920       | 7191        | 388                    | 7579  |

### Table 3. Statistical Table of Flood regulating Process (initial regulated water level 291m)

| Time  | BaiS inlow | BaiS outflow | BaiS -Hongs Interzone | Hongs inlow | Hongs outflow | BaiS inlow | BaiS outflow | BaiS -Hongs Interzone | P=0.1% |
|-------|------------|--------------|------------------------|-------------|---------------|------------|-------------|------------------------|-------|
| 8.23.4 | 1270       | 1270         | 371                    | 1641        | 1641          | 1170       | 1170        | 267                    | 1437  |
| 8.24.1 | 2180       | 2180         | 410                    | 2590        | 2590          | 2010       | 2010        | 295                    | 2305  |
| 8.25.1 | 3090       | 2500         | 468                    | 2968        | 2968          | 2840       | 2500        | 337                    | 2837  |
| 8.26.1 | 6070       | 2500         | 580                    | 3080        | 3080          | 4750       | 2500        | 417                    | 2917  |
| 8.27.1 | 9050       | 2500         | 1090                   | 3590        | 3590          | 6660       | 2500        | 786                    | 3286  |
| 8.28.1 | 14700      | 2500         | 1770                   | 4270        | 4270          | 10100      | 2500        | 1270                   | 3770  |
| 8.29.1 | 20300      | 2500         | 2300                   | 4800        | 4800          | 13600      | 2500        | 1660                   | 4160  |
| 8.30.1 | 18000      | 6655         | 3450                   | 10105       | 7176          | 12600      | 2500        | 2110                   | 4610  |
| 8.31.1 | 15800      | 9375         | 2180                   | 11555       | 9065          | 11700      | 3835        | 1570                   | 5405  |
| 8.32.1 | 14000      | 10398        | 1540                   | 11938       | 10539         | 10505      | 7065        | 1100                   | 8165  |
| 8.33.1 | 12100      | 10525        | 1140                   | 11665       | 11273         | 9240       | 7193        | 820                    | 8013  |
| 8.34.1 | 10900      | 10573        | 971                    | 11544       | 11467         | 8280       | 7265        | 700                    | 7965  |
| 8.35.1 | 9680       | 10559        | 803                    | 11362       | 11362         | 7320       | 7290        | 578                    | 7868  |
| 8.36.1 | 9080       | 10502        | 671                    | 11173       | 11173         | 6790       | 7279        | 482                    | 7761  |
| 8.37.1 | 8480       | 10419        | 559                    | 10978       | 10978         | 6260       | 7244        | 402                    | 7646  |
| 8.38.1 | 8020       | 9285         | 539                    | 9824        | 9824          | 5920       | 7191        | 388                    | 7579  |

### Table 4. Outcome Table of Flood Control in Review Reports on the Pivotal Project of Recovering Reserved Reservoir Capacity in Hongs Hydropower Station

| Project | 0.1% | 1% | Notes |
|---------|------|----|-------|
| 1. initial regulated water level (m) | 290  | 291 | Initial regulated water level(m) |
| 2. max inflow (m³/s) | 11940 | 11940 | approximate rounding |
| 3. max flood stage (m) | 294.6 | 294.6 | Total reservoir capacity: |
| 4. max outflow (m³/s) | 11540 | 11540 | 2.41×10⁶ m³ |
| 5. corresponding tailwater level (m) | 274.67 | 274.67 | 7579 7579 |
By comparing Table 1 and 4, System check achievements is known that the calculation results reviewed have little difference with those in Review Reports on the Pivotal Project of Recovering Reserved Reservoir Capacity in Hongs Hydropower Station. Within the range of allowed errors, it indicates that the system calculation results are reasonable.

For convenient use, analyze and synthesize all minds of information, improve ZedGraph charting class libraries and bind DataGridView control to provide the function of comprehensive information inquiry (such as reservoir eigenvalue, characteristic curve, flood process, etc.), see figure 5. The control conditions shown in Figure 6 is that system outputs control condition info in Word document by loading WebBrowser control, with great help and guiding significance to carry out flood regulation calculation.

5. Application Example

![Figure 4. Basic Information Diagram](image)

![Figure 5. Control Conditions Diagram](image)
Based on above requirement analysis and function design, take flood regulation in Hongs pumped storage power station as a study case, design and develop a flood regulation system for lower storage reservoir of Hongs pumped storage power station, as a decision support system to formulate flood control scheme for lower storage reservoir of Hongs pumped storage power station. This system includes two major categories: information management and advance applications needed by flood regulation system, flexibly modify model parameters and setting conditions through human-computer interface, providing key decision support to confirm the characteristic water level of lower storage reservoir of Hongs pumped storage power station.

### 6. Conclusions

This article analyses ordinary requirements of reservoir flood regulation business, puts forward the framework design ideas and system functional structures of reservoir flood regulation system, and explores the design and development of the function modules like database management, flood regulation calculation, information inquiry and so on. Centering on database, conduct excellent database chart design, and based on C/S structure, establishes an overall computerized process from data extraction, analysis and processing to flood regulation calculation, outcome inquiry and data compiling. At last, introduces the application situation of flood regulation system to lower storage reservoir of Hongs pumped storage power station. The research result of this article is able to provide reference to the construction of reservoir flood regulation system and improvement of management system.

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### 8. References

[1] Zhang Kecheng, Hydroenergy Design of Pumped Storage Power Station[M]. Beijing: China Waterpower Press

[2] Wang Chunhui, Flood Regulation Calculation for Hui Zhou Pumped Storage Power Station[J]. Hydropower, 2009,35(7):17-19

[3] Zhang Danqing, Flood Regulation Analysis on Heimifeng Pumped Storage Power Station[J]. Hydropower, 2010,36(7): 28-30

[4] Bai Chongyu, Huang Ming, Wei Qing, etc., Dam Safety Monitoring System construction and implementation methods based on Visual Studio platform [J]. Hydropower Energy Science,2012,4(31):164-166+197.

[5] Li Xiangchun, Yu Hong, etc. Review Reports on the Pivotal Project of Recovering Reserved Reservoir Capacity in Hongs Hydropower Station[R].China Water Northeast Survey Design Research Co.,Ltd, Jan. 2007

[6] Zhiqiang Jiang, Hui Qin, Dechao Hu, Changming Ji, Jianzhong Zhou. Effect Analysis of Operation Stage Difference on Energy Storage Operation Chart of Cascade Reservoirs.Water resources management, 2019

[7] Zhiqiang Jiang, Changming Ji, Hui Qin, Zhongkai Feng. Multi-stage Progressive Optimality Algorithm and its application in energy storage operation chart optimization of cascade reservoirs. Energy, 2018, 148:309-323