ShiTouzhai hydropower station hub layout pattern comparison research of pre-feasibility study stage

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Abstract. The selection of the layout scheme is the key content of the pre-feasibility study of large and medium-sized hydropower stations. Based on the topographical and geological conditions, and considering the construction conditions, reservoir flooding, project investment and other factors, this paper makes an in-depth analysis of the layout comparison and design of the pre-feasibility stage of Shitouzhai Hydropower station, in order to provide beneficial inspiration for similar project design.

1. Introduction
Preliminary determination of representative dam site, primary representative dam type, hub layout and main building types are important work contents in the stage of pre-feasibility study of hydropower projects[1]. Topographic factors such as the topography of the river reach at the dam site, the height of the river bed, the width and width of the channel plane and the length of the straight river reach, the steep and gentle natural slope of the riverbank, as well as geological conditions at the dam site have a significant impact on the layout, construction conditions and project investment of the hydropower station[2-3]. This paper makes an in-depth analysis of the layout comparison and design of Shitouzhai Hydropower Station in the pre-feasibility stage in order to provide useful inspiration for similar engineering design.

2. Project summary
Shitouzhai Hydropower Station is the tenth stage of the 13-stage development plan of two reservoir in the middle and lower reaches of the Nujiang River. Its upstream is Liuku hydropower station, and its downstream is Saige hydropower station. The station is about 31 km away from the highway in Liuku town, where the Nujiang Prefecture is located, and 636km away from the Kunming Highway, with convenient transportation. The main task of power station development is to generate electricity, and it also has comprehensive benefits such as irrigation, water and soil conservation and tourism. In the pre-feasibility stage, the reservoir checks the flood level of 786.94 m, with the total storage capacity of $1.13 \times 10^8 \text{m}^3$, the normal storage level of 784m, the corresponding storage capacity of $0.951 \times 10^8 \text{m}^3$, and the regulated storage capacity of $0.345 \times 10^8 \text{m}^3$, with the daily regulation performance. The dam is 54.5m high with a total installed capacity of 520MW.

3. Dam section choice
Shitouzhai Hydropower Station is about 35km away from Liuku Hydropower Station in the upstream, and the main submerged objects in the reservoir area are the new settlements on the other side of the river.
Wanqiao Village, the farmland and villages along the Yangtze River in Shangjiang Township. The New village and the secondary highway from Jinchangling to Liuku, etc. If the connection between the cascade power stations is considered, the town will be greatly submerged. The river valley from Liuku to Shangjiang Township twists and turns and slopes gently. Gully tributaries on both sides are developed, gully mouth topography is gentle and open, there are cultivated land and residential areas on the gentle slope platform, there is no suitable dam site location.

The left bank, 4km upstream of the original planned dam site, is the large tributary Sunzu River, and the right bank is the diluvial fan accumulation area of tributary Binggong River, with open topography. On the right bank, 1km downstream, there is a Bonwa river. The gully is piled up by diluvial fans and the terrain is open. The right bank of the section from Banwa Creek to Shuanghongqiao has more open terrain, which is a key area for the development of the hot zone in Baoshan City, Yunnan Province. The construction of the dam here will bring great flood losses, difficulties in resettlement of migrants, damage to provincial cultural relics, and reduce the scale of Saige power station, etc. On the reach of about 4km between Sunzu River and Banwa River above the key area of thermal development in Baoshan City, the left bank has relatively complete terrain and stable natural bank slope. Hard rock, shallow rock weathering. The karst phenomenon in the dam area is not developed, and the geological conditions for building the concrete gravity dam with medium dam height are available. The v-shaped transverse valley terrain with slightly symmetrical width and slowness is suitable for the transverse expansion of hub buildings and the layout of riverbed power station hub. The overland terrace on the bank is convenient for the layout of diversion buildings.

4. Hub layout scheme comparison and selection

4.1. In the dam site primary
In the selected dam section, the upper dam site on the 1km - 2km reach downstream of Sunzu River, a tributary on the left bank, and the lower dam site on the 1km reach upstream of Banwa River on the right bank are initially proposed for comparison selection according to hydrological, topographic and geological conditions.

The upper dam site is a transverse valley with gentle terrain, shallow weathering of rock mass, no obvious unloading, no large structural plane distribution in the building area, high strength of rock mass, good uniformity. Dam area karst phenomenon does not develop, is a weak karstification section. The site of the lower dam is inclined valley, except for partial slate, the weathering and unloading are shallow, and the rock mass strength is generally high. The upper and lower dam sites all have the engineering geological conditions for building medium dams and high concrete gravity dams.

4.2. Hub layout scheme comparison and selection
The project area is flat and open, with strong mountains on both sides and complete terrain. It is suitable for horizontal layout of buildings to facilitate the layout of flood discharge buildings and solve the problem of flood discharge with large flow. The v-shaped valley terrain with slightly symmetric width and width is suitable for the layout of riverbed hub integrating water retention, flood discharge, sand washing, water diversion and power generation [4].

From the terrain, general arrangement, construction diversion, dam body concrete gravity dam with available water, building and construction diversion from the local material dam simple can concentrate on the advantages of the riverbed parts [5], in combination with the characteristic of the large flood discharge flow of this project, proposed at the beginning of concrete gravity dam as the upper and lower dam site representative dam type. According to the requirements of topographic and geological conditions, layout of the hub buildings, project scale and operation function, and combined with the construction diversion method, the layout scheme of the hub is determined by considering different layout modes of the flood discharge buildings and power station workshops.
4.2.1. The layout plan of the hub was initially drawn up. The layout of the upper and lower dam sites is compared with that of the riverbed plant, the left bank plant and the right bank plant.

Riverbed powerhouse has compact hub layout, short inlet channel and small head loss, which can make full use of the head and reduce power loss, and the riverbed topography can be used to reduce the amount of plant foundation excavation [6]. When the powerhouse is placed behind the dam, the diversion system is longer than that of the riverbed type, and the head loss is large. It is difficult to satisfy the regulation of the axial flow propeller unit selected in the pre-feasibility stage. Moreover, the foundation pit of the powerhouse is deep, and the excavation amount, concrete amount and foundation treatment amount of the dam section of the powerhouse are larger than that of the riverbed type. According to the comparison and preliminary feasibility study stage, the type of the workshop is preliminarily determined as riverbed type workshop.

According to the topographic conditions of the upper and lower dam sites and the research results of the layout of hydraulic structures, the flood discharge structures in the upper and lower dam sites can be arranged in the main river channel as well as in the floodplain terrace. Combination of diversion and diversion structures arrangement, fitting on the left bank of dam site in the early factories open channel diversion scheme, the right tunnel diversion scheme, under the left bank of dam site factory open channel diversion scheme, the right tunnel diversion scheme and the right factory stage diversion scheme, a total of five for further deepening design, based on this, advances the scheme of civil construction, construction scheme and corresponding investment.

4.2.2. Hub layout scheme comparison and selection. (1)The axis azimuth of the upper dam site is SE159°31 '49 " , and the crest elevation is 789.50m. The dam crest length is 404.2m, and the highest dam height is 62.5m in the dam section of the plant. A 160m wide floodplain terrace on the left bank is used to arrange the dam section of the workshop and the spillway surface hole is arranged in the main channel. Along the dam axis, the pivot buildings are successively from left to right: the left bank non-spillway section, the left sandy bottom hole section, the powerhouse section, the right sandy bottom hole section, the spillway section, the middle non-spillway section, the spillway section and the right bank non-spillway section.

(2) In this scheme, the tunnel diversion structure does not occupy the position of the dam section, so the length of the dam crest is smaller than that of the left bank powerhouse, which is 377m. The maximum height of the dam is located in the spillway section, which is 62.5m. Left bank floodplain terrace layout flood buildings, the right bank main channel layout of the dam section of the plant. Along the axis of the dam, the pivot buildings are successively from left to right: left bank non-spillway section, spillway dam section, left sandy bottom hole section, powerhouse section, the right sandy bottom hole section, the spillway section, the middle non-spillway section, the spillway section and the right bank non-spillway section.

(3) The axis azimuth of the lower dam site is SW225°20 '51 " , and the crest elevation is 789.500m. The dam crest length is 411.00m and the maximum dam height is 54.5m. In order to cooperate with the construction of longitudinal cofferdam and the layout of diversion open channel, the dam section of the factory building is arranged in the main river channel, and the flood discharge building is arranged on the floodplain terrace with a width of about 200m on the right bank. In order to reduce the amount of dam excavation and concrete and satisfy the layout of longitudinal cofferdam, the overflow surface hole is divided into two parts and a non-overflow dam section is set in the middle. The layout of the pivot buildings along the dam axis is the same as that of the open channel diversion scheme of the workshops on the left bank of the dam site.

(4) The scheme is tunnel diversion, and the layout of the junction buildings is not affected by diversion buildings. Therefore, the flood discharge buildings are arranged in the main river channel, and the dam section of the factory building is arranged on the floodplain terrace with a width of about 200m on the right bank. The length of the dam crest is 400.10m and the maximum height of the dam is 54.5m. The layout of the pivot buildings along the axis of the dam is the same as that of the tunnel diversion scheme for the workshops on the right bank of the upper dam site.
(5) The dam crest length is 454.05m and the maximum dam height is 54.5m. The layout of the spillway buildings and the dam section of the workshop is the same as the diversion scheme of the tunnel of the workshop on the right bank. Along the axis of the dam from left to right, the pivot buildings are successively: the left bank non-spillway section, the left spillway section, the middle non-spillway section, the right spillway section, the sandy bottom hole section, the powerhouse section, and the right bank non-spillway section.

4.2.3. Comparison of representative schemes of hub layout. According to the topographic and geological conditions of the upper dam site, the layout scheme of the hydraulic hub and the preliminary economic analysis, it can be concluded that:

(1) The upper dam site has the topographic and geological conditions for the construction of concrete gravity dam and riverbed type workshop. From the layout of the hydraulic hub, the two schemes are technically feasible.

(2) The total construction period of the left bank workshop open channel diversion scheme is 61 months, compared with the right bank workshop tunnel diversion scheme (the total construction period is sixty-three months) save two months, with the advantages of early completion, early power generation, early effectiveness and so on.

(3) After the initial investment estimation, civil engineering investment on the right bank diversion tunnel diversion scheme is on the left bank factory channel scheme province 61.5867 million yuan, in the left bank of the diversion project investment open channel diversion scheme is on the right bank factory tunnel diversion scheme province 342.3633 million yuan, the comprehensive calculation, on the left bank open channel diversion scheme than the right factory tunnel diversion scheme to save investment of 280.7766 million yuan. The scheme of open channel diversion for the left bank workshop of upper dam site has the advantages of superior technical conditions, short construction period and less investment, so it is recommended as the representative scheme of the layout of the hub of the upper dam site.

The comparison and selection scheme of the layout of the three junctions at the lower dam site has similarities with that at the upper dam site. The total construction period of the open channel diversion scheme for the left bank powerhouse is sixty-four months, the total construction period of the tunnel diversion scheme for the right bank powerhouse is sixty-seven months, and the total construction period of the phased diversion scheme for the right bank powerhouse is sixty-seven months. The civil construction and diversion project investment of the open channel diversion scheme of the left bank workshop is 240,659,000 yuan less than that of the tunnel diversion scheme of the right bank workshop, and 610,421,400 yuan less than that of the staged diversion scheme of the right bank workshop. Based on the comprehensive comparison, the open channel diversion scheme of the left bank workshop is recommended as the representative scheme of the hub layout of the lower dam site in the pre-feasibility stage.

The main quantities of each scheme are shown in Table 1.

| Subjects                      | Unit     | The upper dam site | The lower dam site |
|-------------------------------|----------|--------------------|--------------------|
|                               |          | Left bank workshop open channel diversion scheme | Right bank workshop tunnel diversion scheme |
| Earth and stone are clearly excavated | 10^4 m³ | 170.346 | 146.676 |
| Regarding the adit dig | 10^4 m³ | 0.078 | 0.078 |
| Earth and stone backfill | 10^4 m³ | 15.821 | 17.995 |
| Concrete steel | t | 106.301 | 105.801 |
| reinforced steel | t | 45786 | 43904 |
| Steel | t | 364 | 364 |
| Concrete | 10^4 m³ | 99.840 | 98.272 |
| Phased diversion scheme for the right bank plant | | 163.550 | 110.267 | 44241.9 |
4.3. Comparison of dam site

Based on the comprehensive technical and economic comparison of the representative schemes of the upper and lower dam site junction layout, the following conclusions are drawn:

(1) The topographic conditions of the upper and lower dam sites are similar, the upper dam site is slightly narrow, both of them meet the topographic and geological conditions for building concrete gravity dam and riverbed type workshop, and the engineering geological conditions of the upper dam site are slightly better than that of the lower dam site.

(2) The adjusted storage capacity of the lower dam site is about 791×10^4 m³ than that of the upper dam site. The upper dam site has no adjustment ability, and the lower dam site can reach daily adjustment. The installed capacity of the lower dam site is increased by 40MW, ensuring that the output is increased by 12.42MW, the annual average generating capacity is increased by 2.881×10^8 kw.h, the annual utilization hours are increased by 179h, and the rated water head is increased by 2.5m. The lower dam site is obviously superior to the upper one.

(3) The floodplain of the upper dam site has deep alluvial layer, low foundation surface of the dam body, the maximum dam height is 8m higher than that of the lower dam site, and the volume of excavation and concrete of the hub is large. The lower dam site due to the shallow alluvial layer, the foundation is higher, the dam height is correspondingly lower. The lower dam site is superior to the upper dam site according to the amount of engineering and economic analysis.

(4) The investment difference between the upper and lower dam sites mainly consists of two parts: submerged compensation static investment and construction auxiliary project investment. The total static investment at the lower dam site was 385.32 million yuan higher than that at the upper dam site, but the total revenue from power generation sales was 864 million yuan higher than that at the upper dam site. Therefore, the lower dam site has obvious economic advantages.

5. conclusion

Based on the comprehensive comparison, the open channel diversion scheme of the left bank of the dam site is selected as the recommended hub arrangement scheme in the pre-feasibility stage. The method of selecting the dam site and the layout of the hub in the pre-feasibility stage of the power station can provide a reference for the design of the pre-feasibility of similar large and medium-sized power stations in the future.

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