KEY AND DIFFICULT PROBLEMS AND COUNTERMEASURES OF BAIHETAN HYDROPOWER STATION DAM OPERATIONAL MANAGEMENT

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ABSTRACT

Baihetan hydropower station is currently the largest hydropower project under construction in the world. after completion, it will become the second largest hydropower station in the world. the project is mainly composed of river dam, diversion power generation system and flood discharge and energy dissipation facilities. the project is large in scale and the structure of facilities and equipment is complex.combining with engineering design, construction and special meteorological conditions, this paper makes a comprehensive analysis of the key and difficult problems that baihetan dam and related facilities and equipment may face in operation and management, and puts forward the problems that should be paid attention to the key management objects such as dams, slopes and underground caverns,some preliminary solutions have been put forward to solve the difficulties in the operation of stratified intake gate, on-line monitoring of large metal structure and operation of gate crane in windy weather. some projects have been started to prepare for the operation and management of the project.

Keywords *: Baihetan hydropower station;Dam management;Important and difficult problems; Countermeasures.*

1. PROJECT OVERVIEW

Baihetan hydropower station is located in the main stream section of jinsha river at the junction of ningnan county of sichuan province and qiaojia county of yunnan province. the upstream of the power station is connected with wudongde power station, and the downstream is adjacent to xiluodu power station. It is the second level of the four cascade power stations in the downstream of jinsha river. the development task of the project is mainly to generate electricity, take into account flood control, shipping, and promote local economic and social development. it is one of the backbone power supply points of the power transmission from west to east, It is the largest hydropower project under construction in the world at present. after completion, it will become the second largest hydropower station in the world, with a total reservoir capacity of 20.6227 billion cubic meters, a single unit capacity of 1000 MW, a total installed capacity of 16000 MW and an average annual power generation capacity of 62.443 billion kwh.

Baihetan project started preparation in june 2011, the excavation of underground powerhouse was started in june 2014, the river closure was realized in november 2015, the main body of dam concrete was poured in april 2017, the unit installation was started at the end of 2019, the reservoir was impounded in april 2021, the first batch of units were put into operation in july 2021, all units were put into operation in june 2022, the project was completed in june 2023, and the total construction period of the project was 12 years.

2. DAM AND RELATED EQUIPMENT

Baihetan hydropower station dam related equipment includes hydraulic structure, gate dam metal structure equipment, lifting equipment, slope foundation and river water area, etc. baihetan project has a large scale. the dam is the most important infrastructure equipment of the project, with a large volume, complex structure, many types and quantities. the permanent hydraulic structure of the project is composed of river blocking dam, flood discharge and energy dissipation structure, water diversion and power generation system, etc.; large metal structure equipment includes all kinds of gates, hydraulic headstock gear and steel lining of flow channel, etc.; hoisting equipment includes bridge crane, gantry crane, trolley and elevator, etc.

The dam is located in the middle of the river bed, which is a concrete double curvature arch dam with a crest elevation of 834m and a maximum dam height of 289m. the downstream of the dam is provided with a water cushion pond and

a second dam. the flood discharge facilities of the hub include 6 surface holes and 7 deep holes located in the dam, and 3 flood discharge holes located in the mountain on the left bank. the water diversion and power generation system adopts the development plan of the head of the underground powerhouse, which are arranged symmetrically on the left and right banks, respectively, and the powerhouse eight water turbine generator units with a capacity of 1000MW are installed respectively in the water diversion tunnel. the water is supplied by a single unit and a single pipe. the tailrace system shares one tailrace tunnel for two units. four tailrace tunnels are arranged on the left bank and the right bank respectively, among which three tailrace tunnels are combined with the diversion tunnel on the left bank and two tailrace tunnels are combined with the diversion tunnel on the right bank.

The metal structure gate includes intake trash rack, layered intake gate, access gate, fast gate, draft tube access gate, tailrace tunnel access gate, deep hole accident (access) gate, deep hole working gate, surface hole working gate, fault (access) gate and working gate of the spillway opening of the dam, including 80 trash racks (240 lifting units), layered water intake gate there are 80 gates (800 hoisting units) and 61 sets of gates,total weight over 30000 tons; the hydraulic headstock gear includes 35 sets of unit quick gate hydraulic headstock gear, deep hole hydraulic headstock gear, surface hole hydraulic headstock gear and spillway tunnel hydraulic headstock gear; the steel lining of channel includes 23 sets of water diversion pressure pipeline steel lining and deep hole channel steel lining.

Baihetan power station has 91 set of lifting equipment,the bridge crane mainly consists of four 1300/160 ton bridge cranes and two 160/160 ton bridge cranes for the power house, in addition, it also includes GIS room bridge crane, GIL maintenance bridge crane, deep hole hoist room bridge crane, drainage pump room bridge crane, unit water truck room circular crane and other small lifting equipment; the gantry crane includes dam top gantry crane, flood discharge tunnel water inlet gantry crane, power station water inlet gantry crane; the gantry crane includes unit draft tube maintenance gate gantry crane and tailrace gate crane water tunnel bulkhead gate trolley; the elevator includes dam elevator, outgoing shaft elevator, plant elevator and control building elevator.

3. KEY AND DIFFICULT PROBLEMS IN OPERATION MANAGEMENT AND COUNTER MEASURES

3.1 Dam safety management

Dam safety management is the core work of project operation management. the maximum dam height of baihetan dam is 289m, ranking the third in china. It is a 300m high arch dam with a concrete volume of 8.03 million cubic meters, which is divided into 2301 silos for pouring. the dam site is located in the area of strong earthquake, with high seismic intensity. the dam is fortified as IX degree, with a design seismic peak acceleration of 451gal. the water thrust of the dam is 16.5 million tons, second only to that of the dam xiaowan dam ranks second in the world with 17 million tons.

A series of technical problems have been overcome in the design and construction of baihetan dam. the valley where the dam is located is asymmetric v-shaped, with gentle slope on the left bank and steep slope on the right bank. the dam section in the high area on the left bank uses concrete cushion. the bedrock in the low area on the left and right banks of the dam uses the first type of columnar jointed basalt, with high development density of columnar joints and developed staggered zones in the layer, which is easy to relax after excavation during the excavation, a series of engineering measures were taken to protect the rock mass to meet the requirements of dam pouring; in order to improve the temperature control characteristics of concrete during the construction, the low heat cement concrete was used for the whole dam, which is the first attempt in the hydropower project; in order to improve the concrete performance of the dam, the limestone aggregate was used for the dam, and the limestone aggregate was mined from the stock yard about 50km away from the dam; and In order to improve the geological conditions of the dam abutment, the dam was deflected along the river center line, and the angle between the dam center line and the river center line was 5°.

The key work of dam safety management is to use the dam safety monitoring system to carefully monitor the displacement, deformation and stress-strain of the dam. at present, the dam monitoring instruments are being embedded with the concrete pouring, and some instruments have begun to acquire data, and the monitoring data analysis has also been carried out. subsequently, with the continued construction and completion of the dam, the first water retaining period of the dam should be completed during the period of the first rise of the reservoir water level to the normal water level and the first fall of the reservoir water level, the dynamic change process of the dam's behavior shall be paid special attention to. the comparison and analysis shall be made with the design indexes, the operation rules of the dam shall be summarized, and the safety monitoring indexes during the operation of the dam shall be gradually established and improved. secondly, the weak links in the design and construction of the dam shall be paid attention to in combination with the characteristics of baihetan dam, such as no symmetrical "v" river valley, left bank concrete pad, the first type of column jointed basalt, the influence of dam center line deflection on dam stress and strain, creep and temperature change process of low heat concrete; in addition, it is necessary to pay attention to the seepage change of dam bedrock to master the working performance of dam foundation and dam abutment anti-seepage curtain.

3.2 Deformation monitoring of valley amplitude in hub area

The excavation of slope has reconstructed the valley slope. the construction of the dam makes the riverbed and the slope rock mass bear huge self weight and water thrust of the dam body. the impoundment of the reservoir makes the

underground water level of the mountains on both sides rise greatly. under the influence of the above factors, the valley of the slope in the hub area is deformed. if the scope of the deformation of the slope is limited to the surface layer, the deformation and supporting measures will play an effective role with the extension of time It will gradually converge and affect the stability of the excavation slope. if the deformation of the slope comes from the deep part of the rock mass, it will cause regional overall deformation, which is manifested as valley deformation. the valley deformation exceeding the design requirements will affect the operation safety of the arch dam project.

After the completion of a domestic project, the long-term continuous shrinkage deformation of the valley affects the operation and management of the arch dam and the plunge pool. there is no significant correlation between the change rate of the valley amplitude and the water level. at present, it has not fully converged, and there is no clear conclusion on the cause analysis. the observation equipment for the valley amplitude deformation of the project is increased in the later period. the first batch of data was obtained at the end of 2012, which is too late.during the design of baihetan dam, the valley monitoring system was planned systematically and the system construction was completed. in 2015, the first batch of data was obtained before the dam was poured, and the continuous observation was carried out. from the current monitoring results, the variation process is stable. because the dam is currently being poured, the impact cannot be determined at this stage.

With the continuous pouring of the dam and the rising of the reservoir water level, we should continue to observe the deformation of the valley amplitude, obtain the complete deformation process of the valley amplitude, and analyze the depth range of the valley amplitude deformation in combination with the surface deformation of the slope. in case of the overall deformation of the dam site area, we need to study the causes of the deformation, and analyze the adverse impact on the operation of the arch dam in time, so as to take countermeasures measures shall be taken to avoid damage to the arch dam structure.

3.3 Stability management of surrounding rock of underground cavern

The powerhouse of baihetan underground power station has a large scale, with a width of 34m above the rock anchor beam, a maximum excavation depth of 88.1m and a length of 438m. the excavation and support of the powerhouse was started in june 2014, and turned into concrete pouring construction after the completion of excavation and support in 2018. It is expected that the concrete pouring and embedded parts installation can be completed by the end of 2020.

The stability of the surrounding rock of the underground cavern mainly exists in the construction period. the underground power station of baihetan project is composed of five main caverns, including the main and auxiliary powerhouse cavern, the main transformer cavern, the draft tube bulkhead gate chamber, the tailrace surge chamber and the tailrace tunnel bulkhead gate chamber. from the comparison of the geological conditions of the underground plant area on the left and right banks, the cavern of the underground power station on the right bank is crossed by the staggered zone between the c4 and c5 layers, so the geological conditions are relatively poor.

During the excavation of the underground powerhouse on the right bank, the local deformation of the upper side wall and the top arch once occurred, which affected the stability of the surrounding rock. after the supplementary support was taken and the water collecting well was adjusted outside the main powerhouse, the deformation of the surrounding rock was controlled. after the excavation of the draft tube maintenance gate chamber and the draft tube surge chamber of the underground powerhouse on the right bank, the deformation of the tunnel wall rock even occurred At present, supplementary support has been completed.

After entering the operation period, it is necessary to continue to do a good job in the stability management of the surrounding rock in the underground plant area, use monitoring instruments to continuously track the subsequent deformation of the surrounding rock in various parts, especially the parts on the right bank for supplementary reinforcement, master the deformation state of the surrounding rock in the tunnel during the operation period, and deal with the parts with abnormal deformation in time; the main power house of the water diversion and power generation system is arranged close to the reservoir, and after the reservoir water rises the underground water level around the underground cavern will rise greatly, and the side wall and surrounding rock of the cavern will face certain seepage pressure. it is necessary to strengthen the patrol inspection of unlined crown of each large cavern, check the stability of local rock mass, and timely clean up or support the loose rock mass.

3.4 Safety management of high head plug near reservoir

Due to the construction needs, many caverns connected with the slope are arranged in the mountain. after the above caverns are sealed, part of the plugs are connected with the reservoir water and bear a large water pressure. if the plugs near the reservoir are damaged, it may cause flooding of the plant and major loss of personnel and property, which is an unacceptable risk for the operation and management of the power station.

There are 126 tunnels to be sealed in baihetan project, including construction adits, traffic tunnels and exploration tunnels. up to now, 44 tunnels have been sealed, and 82 tunnels need to be sealed. the plugs near the reservoir at the upstream of the dam directly bear the reservoir water pressure, among which the cross-section size of the diversion tunnel, diversion bottom hole and traffic tunnel plug during the construction period is large and the water head is high, such as that of the diversion tunnel plug the water head will reach 255m. in order to do well in plug construction, the

design unit and the construction unit also attach great importance to ensure that the cavern should be fully plugged and the quality of plug construction.

According to the overall arrangement of diversion during the construction period of the project, the diversion tunnel, diversion bottom hole and other plugs need to be completed in a dry period. there are many construction procedures and short construction period. it is necessary to seal the gate before lowering the gate and repair the water stop, clean the gate slot underwater to ensure the lowering effect, reduce the water leakage of the gate and avoid passive water blocking before the concrete strength of the plug reaches the standard.

The plug plays a role in the operation period of the project. according to the monitoring instrument, it is necessary to track and monitor its deformation, displacement, stress and strain, seepage and seepage pressure, obtain the first batch of data as early as possible, pay special attention to the working state of the plug during the previous water level rise and fall, carry out continuous analysis, fully grasp the operation state and law of the plug, monitor the abnormal measuring points, and carry out monitoring when necessary make sure the operation of plug is under control.

3.5 Effect tracking of seepage control and drainage system of underground powerhouse

Baihetan underground power house adopts the head type development mode. the underground power house caverns are located in the mountains below the normal water level of 825m in the reservoir area. after the reservoir impoundment, the river water level will rise about 220m on the basis of the natural river water level, and the underground water level of the mountains on both banks will also rise significantly. the seepage field of the underground plant area changes strongly. although the overall rock permeability of the thick layered basalt is small, but faults, interlaminar dislocation zones, compressional fracture zones and joint fissures are developed, and the problem of rock fissure leakage cannot be ignored.

The horizontal buried depth of the underground powerhouse caverns on the left and right banks is between 420m and 1000m. in order to control the seepage drainage of the underground plant area after impoundment, the seepage control system is arranged around the underground plant area, and the drainage system inside the tunnel is arranged. the seepage control system outside the plant is composed of the impervious curtain at the upstream side of the plant and the drainage curtain surrounding the plant and the main transformer room. the drainage system inside the plant is composed of the drainage of the rock wall of the tunnel In addition, seepage intercepting holes are arranged in the interlaminar staggered zone with poor anti-seepage effect to strengthen grouting treatment for the faults passing through the anti-seepage curtain.

Seepage stability of underground plant area is of great significance in operation period. water turbine generator unit, main transformer and indoor GIS equipment are installed in the main plant and main transformer room. leakage water in the installation area of mechanical and electrical equipment will affect the operation safety of the equipment; long-term and continuous seepage of rock mass will make the filler in the interlayer be brushed, the leakage channel will be expanded and the seepage flow will be increased; low-level drainage the seepage water from the gallery will be collected into the leakage water collection well of the power house for centralized pumping, and the excessive seepage water from the rock mass will increase the working load of the leakage drainage pump, affect the service life of the equipment, and have the potential risk of flooding the power house; in addition, after the connection material between the rock blocks is washed away by the seepage water, it may affect the safety of the rock mass, especially the loose rock blocks, causing serious consequences.

After the power station enters the operation period, it is necessary to monitor the seepage pressure of the rock mass in the underground plant area, dynamically evaluate the effectiveness of the anti-seepage curtain, analyze the water quality of the seepage, dredge and maintain the drainage facilities in the plant, ensure the smooth drainage, conduct drainage or grouting sealing for the concentrated leakage points with large leakage, and clean the loose rock mass in the grouting and drainage gallery.

3.6 Monitoring of river regime evolution in the lower reaches

In order to make use of the drop between the downstream tail water of baihetan project and the backwater of xiluodu reservoir, and in combination with the topographic and geological conditions of the downstream river, the river channel is excavated to improve the water head of power generation and give full play to the engineering benefits; according to the design demonstration, the weighted average water head of the power station can be increased by 3.17m and the electric power can be increased by 1.028 billion through selective regulation of the 6km river channel downstream of baihetan dam site kwh.

Due to the influence of slope excavation, rock fall, cofferdam removal and river sedimentation, the downstream river regulation boundary has changed greatly. the underwater topographic survey shows that the river bed thalweg from the second dam to the tailrace outlet section is raised from 580m to 590m, which is 10-15m higher than the original shape of the natural river. the residual rock ridge at the tailrace outlet is 6-8m higher, and the bottom elevation is raised from 580m to 586-588m, at present, the underwater topography of the tailrace outlet has seriously affected the normal power generation head; in addition, the temporary construction road during the treatment of the no.11 accumulation slope at the outlet of the spillway tunnel has seriously occupied the river channel overflow section, which has a significant effect on the water level rise in the tailrace outlet area, so it is necessary to adjust the downstream river regulation scheme.

In March 2019, the owner organized and held the review meeting of the design report of the downstream river regulation project. the designer proposed to use the two dry seasons of 2019 and 2020 to complete all the regulation work of the downstream river in advance, but in combination with the construction difficulty and safety risk, after discussion at the meeting, the scope and method of the regulation proposed by the design were agreed. in terms of the implementation opportunity, the meeting proposed the implementation in two phases, in the first phase, the downstream cofferdam, the rock ridge at the outlet of tailrace tunnel and the occupied area at the outlet of flood discharge tunnel will be renovated in 2019 and 2020 to meet the functional requirements of power generation operation. In the second phase, after the operation of the power station, according to the evolution of the river bed, the subsequent treatment plan will be determined through research.

In view of the potential benefits and the current situation of the downstream channel excavation of baihetan project, it is necessary to pay close attention to the first stage regulation results of the downstream channel, and carry out the topographic monitoring of the downstream channel after the project is put into operation, master the evolution of the river regime, analyze the laws, organize and carry out the targeted river regulation, so as to ensure the generating head and benefits of the unit.

3.7 Operation optimization of stratified intake gate of power station intake

According to the prediction results of water temperature in the lower reaches of baihetan power station and the cumulative impact on the water temperature in the lower reaches of xiangjiaba power station , the discharge water temperature of baihetan reservoir and xiangjiaba reservoir is lower than the natural water temperature of the dam site in spring and summer, slightly higher than the natural water temperature in autumn and winter. In order to eliminate the adverse impact of water temperature change, the layered intake gate and gantry crane are set at the water intake of baihetan project.

The bottom sill elevation of the layered intake gate is 736m, and the gate height is 38m, which is divided into 10 sections. There are 800 sections of gates on the left and right banks, one section at the bottom is 2m high, and the other sections are 4m high, which can be interchanged. all the 10 sections of gates enter the gate top elevation of 774m. before the end of february every year, all the layered intake gates are put into the gate slot, the number of water retaining sections of the gate leaf is adjusted according to the change of the reservoir water level from march to june, and the water retaining gates are stored in the storage gate slot in other periods. the layered intake gates are operated by one 4000kN gantry crane (one on the left bank and one on the right bank) and one 2×250kN gantry crane (one on the left bank and one on the right bank) arranged on the top of the intake tower; the layered intake gates need to be operated in two every year from June to june, due to the large number of gate sections, many times of door opening and closing operations, the maximum lifting height is 98m, the single operation takes about 1 hour, the operation task is extremely heavy, which is a great test for operators and equipment.

In order to solve the above problems, during the design of 2×250kn gantry crane at the intake, corresponding interfaces are reserved. after the gantry crane is installed, it is planned to carry out automatic transformation of the gantry crane to realize automatic walking, positioning, grabbing and lifting of the gate, improve the working efficiency and reduce the working intensity. after the power station is put into operation, the analysis and Research on the effect of layered water intake shall be done to explore the law and optimize the water intake stratification, realize multi section combined opening and closing, reduce the number of operations.

3.8 On line monitoring of large metal structure equipment

Large metal structures include large gates, gantry cranes and hydraulic headstock gear, which are complex in structure, bear huge load, and require high strength and stability of the structure. at present, through regular in-service inspection of metal structures to understand the working status of the equipment, in-service inspection has high safety risk, construction difficulty, and can not obtain real-time data, which is the blind area of equipment management.

Metal structure monitoring project mainly includes stress-strain, vibration and operation attitude. with the help of advanced monitoring components and data transmission means, large metal structure can realize online monitoring and real-time grasp the working state of equipment.

According to the preliminary planning, it is planned to install the online monitoring system in the radial gate after the power station is put into operation. the system adopts a hierarchical and distributed structure, which is composed of sensor unit, data acquisition unit and workstation unit. the layout is divided into three levels: sensor layer, data acquisition layer and control display layer. the sensor layer is the monitoring components arranged on the equipment, and the monitoring of some equipment the measuring components shall meet the requirements of long-term underwater operation, and the data acquisition layer is responsible for filtering and sorting the data collected by the sensor; the control display layer includes the switch, server, display unit, etc.; after the sensor obtains the analog signal, it is transmitted to the data acquisition device set in the site, converted into digital quantity and uploaded to the information management system, and the system is equipped with three-dimensional gate safety full evaluation model and alarm value, automatic analysis of the operation status of the gate metal structure.

For the hydraulic headstock gear, it is also planned to add online oil quality monitoring facilities. by automatically taking out oil samples and testing, monitoring oil quality parameters such as hydraulic oil particle size and water content, the quality of oil can be mastered online. It is planned to arrange a certain number of high-definition video probes around the piston rod to transfer the collected image data to the video image analysis system to automatically identify the surface state of the piston rod.

3.9 Outdoor gantry crane operation in windy weather

Baihetan project is located in the subtropical monsoon area. Influenced by the westerly circulation in the South Branch of the Qinghai Tibet Plateau, the westerly circulation prevails in the winter half year. The jinsha river valley is deep and the terrain elevation difference is large, which forms an obvious three-dimensional vertical climate and frequent gale weather in the valley area.

The analysis of the observation data of xintian village meteorological station (located at the dam abutment on the left bank) in baihetan dam area shows that the average number of days with daily extreme wind speed above level 7 from 2012 to 2014 in this area is 241 days, accounting for 66.0% of the total number of days in the whole year, including 178 days in the dry season (January to April, October to December), accounting for 84.0% of the number of days in the dry season; 64 days in the rainy season (may to september), accounting for 35% of the number of days in the rainy season. from the perspective of distribution period, the daily occurrence period of maximum wind speed above level 7 in xintian station from 2012 to 2014 is analyzed. the average proportion of maximum wind speed from 21:00 to 02:00 of the next day is 32.8%, and the average proportion from 17:00 to 04:00 of the next day is 60.4%.

According to china's management regulations, the overhead gantry crane shall be stopped in case of gale above level 6. the unit water inlet and dam crest of baihetan hydropower station are equipped with gantry crane, which is respectively responsible for the opening and closing of unit trash rack, layered intake gate, unit access gate and dam deep hole accident (access) gate, which is related to accident emergency, equipment maintenance and equipment operation.

Frequent gale weather will affect the production work arrangement. in order to reduce the impact of gale weather on the production work, after the operation of the power station, it is planned to carry out more detailed gale observation on the water inlet of the power station and the dam crest area, analyze the occurrence period, duration and other factors of gale, summarize the general rule, and explore the realization means of gale prediction in local areas, so as to provide a section for the corresponding production arrangement the basis of learning also provides guarantee for the safety of gantry crane equipment and operation.

3.10 Deep mining of safety monitoring data

Safety monitoring is an important means to understand the operation status of all kinds of buildings. the monitoring instruments arranged in baihetan project include stress-strain, displacement and deformation, seepage pressure, hydraulics, dynamics, dam body temperature, environmental quantity, etc. there are more than 13000 kinds of instruments, covering the scope of large dam, water cushion pond, second dam, flood discharge tunnel, underground powerhouse cavern group, slope, etc.

At present, monitoring data rely on manual collection and input, the collection efficiency is low. after the formation of safety monitoring system, monitoring data can be automatically collected, integrated and put into storage, and a large amount of data can be obtained. however, from the current situation, the analysis of monitoring data mainly focuses on the simple time sequence process analysis of the monitoring data of a single measuring point, or a small number of variables through correlation analysis, the results obtained are relatively single and fail to give full play to the effect of massive data.

After the project is put into operation, the construction of safety monitoring automation system should be completed as soon as possible, and the monitoring information management system should be improved. based on this, the three-dimensional visualization model of hub and main buildings should be established. with the current rapid development of big data technology, the comprehensive analysis of regional, multi measuring points and multi variables should be carried out, and the overall operation status of regional buildings should be comprehensively and systematically mastered. after continuous exploration In order to provide scientific basis for the operation and management of the project, it is necessary to gradually establish the safety monitoring index of the building.

4. EPILOGUE

Baihetan hydropower station will be put into operation in July 2021 for power generation. many problems have been solved during the construction period of the project, and there are still many problems to be solved during the operation management period. In this paper, based on the design and construction conditions, the more important problems in the operation management of the dam are comprehensively sorted out, and the relevant countermeasures and measures are put forward, which will lay a solid foundation for the operation management of the project and help to realize the long-term development of the project at the same time, it also provides a useful reference for the operation management of similar projects.