Research on Construction Control Network Technology of Hydropower Project in Steep Mountainous Area

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Abstract. Due to the limitation of natural geographical conditions, many hydropower hub projects are built in steep mountainous areas, which leads to difficulties in fabric control network, excessive deformation of side length projection length, long error transmission route, and low precision of control network. The accuracy of the entire control network is difficult to control. This paper discusses the establishment of a planar control network using a high-precision dual-frequency GPS receiver instrument. The elevation control network is built using precision leveling plus triangular elevation measurements. It is proved by examples that the control network established by this method can not only ensure the overall accuracy and overall consistency of the control network, but also achieve economic, rapid and efficient effects.

1. Introduction

The hydropower project refers to the comprehensive task of hydropower generation as the main task, consisting of water retaining structures (dams, gates, riverbed plants, etc.), drainage structures, water diversion systems and hydropower plants, transformer fields, switch stations, etc. [1-3]. With the development of the national economy, the hydropower hub project has developed very rapidly. Due to the limitation of natural geographical conditions, many hydropower hub projects are built in steep mountainous areas, which leads to difficulties in fabric control network, excessive deformation of side length projection length, long error transmission route, and low precision of control network. The accuracy of the entire control network is difficult to control [4-7]. This paper takes the hydropower hub project of Muzaffarabad in Assad Kashmir as an example to discuss the design optimization and construction of the construction control network of the hydropower project in steep mountainous areas[8-10].

The GPS control network uses a side connection and a network connection to deploy the network. This observation method has better graphic strength and higher work efficiency. Before the daily field observation, the calculation personnel will forecast the satellite according to the received ephemeris of the day, determine the best observation time, and formulate the observation plan according to the GPS network design according to the number of receivers. The field observation data is created by the observation date, and the daily observation data is stored in a folder in the same directory for each receiver data for management.
2. Project Overview

The project is located in the Muzaffarabad district of Assad Kashmir. The area is steep and mountainous, with a height of between 900m and 1000m. The project is divided into three main areas: the head, the middle and the tail. The first is located in Nausai/Panjkot, east longitude: 73°43′ north latitude: 34°23′, altitude is about 1000m, the main building here is dam, grit chamber and water inlet, about 41 km from Muzaffarabad. Central in Thotha/ Majhol, east longitude: 73°35′ north latitude: 34°15′, altitude is about 800m, main building is A3, A4 branch hole; tail is located in Chattar Kalas/Zaminabad, east longitude: 73°29′ north latitude: 34°12′, the altitude is about 700m, the main buildings are underground powerhouse and tail water hole. The total length of the diversion tunnel is 28.55km, which is the control project of the whole project. The plane part of the construction control network adopts GPS static mode, and 39 sides are observed by the total station instrument to verify the reliability of the GPS plane control network. The elevation control network is developed by the precision level line and a series of precision level lines. The photoelectric distance measuring triangle elevation network is composed, the three construction areas are connected by precise level, and the construction area adopts triangular elevation.

3. Plane control network

3.1. Layout of plane control outlets

According to the general layout plan of the Muzaffarabad Hydropower Project and the topography of the geographical location, combined with the GPS control measurement specifications, the focus should be on the good visibility, convenient transportation, stable foundation and long-term preservation. Place; when the network is selected, the point is far away from the high-power radio source, high-voltage line, etc.; the GPS network should have a wide field of view, which is conducive to the reception of satellite signals. According to the above principles, a total of 34 plane control points are selected. These control points are: the first Nausai area: 10 common plane control points, 3 original GPS points of the owner (numbered as GPS-5, GPS-7, GPS-N15), and 3 original target points (No. NJ101~NJ103), 3 new buried pier points in the dam and grit chamber (numbered as NA1~NA3); central Thotha/Majhol area: 9 selected plane control points, 2 original GPS points of the owner (No. GPS-2, GPS-4), 6 original mark points (numbered NJ204~NJ205, NJ207~NJ210), newly buried hole A300 near A3 hole; factory and tail water Chattar Kalas/Zaminabad Area: 15 plane control points are selected, the owner has 3 original GPS points (numbered as GPS-A3, GPS-A8, GPS-A9), and the original mark points are 12 (number NJ301~NJ307, NJ310~NJ314).

3.2. Plane control network

Firstly, select 9 points with good position, stability and good graphical condition in the plane control point to carry out regional joint measurement, and they measure the GPS observation time for not less than 150 minutes to increase the accuracy and reliability of long-side observation. Among them, the Nausai area joint measurement points are GPS-N15, GPS-5, GPS7, the Thotha/Majhol area joint measurement points are GPS-2, GPS-4, NJ207, and the Chattar Kalas/Zaminabad area joint measurement points are GPS-A3, GPS- A8, GPS-A9.

The GPS control network uses a side connection and a network connection to deploy the network. This observation method has better graphic strength and higher work efficiency. Before daily field observation, the calculation personnel will forecast the satellite according to the received ephemeris of the day, determine the best observation time, and formulate the observation plan according to the number of receivers in the operation according to the GPS mesh design.

3.3. Plane control network data processing

3.3.1 GPS baseline vector solution
This project adopts Trimble Business Center (hereinafter referred to as TBC) 2.6, which is the commercial software of American Tianbao Company. The partial solution solves the time period and eliminates unhealthy satellites. In the baseline solution process, the ephemeris data is downloaded from the official website's broadcast ephemeris file by Internet, and the ambiguity is fixed by double difference. The baseline height of the satellite solution is set to 15 degrees. Through quality analysis, 132 points of the baseline side for the adjustment calculation are eliminated after the baseline with large error is removed without affecting the mesh shape, and the number of closed loops calculated by 3 sides is 382. The accuracy statistics are shown in Table 1 and Table 2 below:

| Base line name     | length(m) | Residual(m) | ratio  | Remarks     |
|--------------------|-----------|-------------|--------|-------------|
| GPS-A9—GPS-A3      | 989.661   | 0.002       | 2.0ppm | Minimum residual |
| GPS-A3—NJ305       | 3357.577  | 0.005       | 1.4ppm | Maximum residual |
| NJ302—NJ303        | 278.792   | 0.003       | 11.8ppm| Shortest side |
| GPS-5—NJ207        | 202270.612| 0.005       | 0.2ppm | Longest side |
| GPS-7—NJ207        | 19568.139 | 0.003       | 0.14ppm| Minimum ratio |
| NJ302—NJ303        | 3184.177  | 0.004       | 1.2ppm  | average     |

| project            | length (m) | Δ3D  | ΔLevel | Δvertical | PPM    |
|--------------------|------------|------|--------|-----------|--------|
| best               | 0.001      | 0    | 0      | 0.137     |        |
| Worst              | 0.069      | 0.032| 0.067  | 9.424     |        |
| Average ring       | 8123.657   | 0.016| 0.006  | 0.014     | 2.719  |
| Standard error     | 9965.551   | 0.022| 0.008  | 0.02      | 1.795  |

It can be seen from the above table that the baseline residual and the ring closure difference are small, and only the ratio of the short side NJ302-NJ303 is 11.8 ppm, which is mainly due to the short length of the side, and the residual of the side is only 3 mm. The accuracy of this side is reliable. From the baseline solution and the closed difference analysis, the baseline calculation of the whole network is of good quality and high reliability.

3.3.2 Adjustment calculation
The control network adjustment uses commercial software TBC 2.60, the standard error source is set to “engineering setting”, the default standard error is set as: horizontal standard error is 5mm+1ppm, vertical standard error is 5mm+1ppm, alignment error is 1mm, antenna The high error is 2mm and the linear error standard is 95%. A total of 129 baseline edges were used in the adjustment, of which 24 were retested, and the retest baseline accounted for 19% of the total baseline. Firstly, the three-dimensional unconstrained adjustment is performed under the WGS-84 coordinate system. After the adjustment accuracy meets the requirements, the input reference point is constrained by the UTM coordinate system.

4. Elevation control network

4.1. Precision leveling
According to the location of the project and the specifications of the precision level measurement, a total of three precision level routes were set up. The three precise level routes and numbers are:
starting from the Garhi Dopatta SBM-13 reference point, along the left bank of the Jhelum River to the working base of the suburb of Muzaffarabad, and then returning to the SBM-13 level starting point to form a level line with a length of about 44 km. The standard line name is GM, numbered according to BM09 to BM18 and NB01; from the suburb of Muzaffarabad, the road is taken to the Zaminabad plane control point NJ305, and then returned to the working base of the suburb of Muzaffarabad to form a standard route with a length of about 54 kilometers. The line name is MZ, numbered according to BM01 to BM08 and M4, M5, TT1, TT2; from the base of the suburb of Muzaffarabad, along the road to the CGGC camp in the Nauzeri area, and back to the working base of the suburb of Muzaffarabad to form a standard route. 84 km, the level line name is MN, numbered according to BM19 to BM39 and C1A, C1B.

This project uses the Leica DNA03 digital level to automatically record observations. For the precise leveling route, the observation procedures are as follows: the “post-pre-pre-post” observation sequence is used for odd-numbered stations, and the “front-back-post-front” is used when it is an even station. Observation order. In order to ensure the correctness and reliability of the observed high difference, the round-trip height difference comparison is performed for each measurement section, and the statistical analysis of the difference of the round-trip measurement of the measurement section is shown in Table 3. According to the calculation of the discrepancies of the round-trip test, the calculation formula of the accidental error in the precision level measurement per km is as follows, and the accidental error of the precision level measurement per kilometer is calculated as shown in Table 4.

\[ M_A = \pm \frac{1}{4n} \left[ \frac{\Delta \Delta}{R} \right] \] (1)

Description: \( \Delta \) express segment round-trip height difference does not match, \( R \) express length, \( n \) express number of segments.

| name | \( \Delta \) total | \( | \Delta | \leq 2\text{mm} \) | \( | \Delta | \leq 3\text{mm} \) | \( | \Delta | > 3\text{mm} \) |
|------|------------------|-------------------|-------------------|---------------------|
|      | number | %    | number | %    | number | %    |
| M-N  | 26     | 24   | 2     | 7.7% | 0     | 0.0% |
| G-M  | 15     | 14   | 0     | 0.0% | 1     | 6.7% |
| M-Z  | 15     | 14   | 1     | 6.7% | 0     | 0.0% |
| \( \Sigma \) | 56 | 52 | 3 | 5.3% | 1 | 1.9% |

Table 4. Statistical table of accidental errors in the measurement of the gauge per kilometer

| name | distance(km) | Accidental error \( M_\Lambda \)(mm) |
|------|--------------|-------------------------------|
| M-N  | 41.94        | 0.45                          |
| G-M  | 21.60        | 0.53                          |
| M-Z  | 27.04        | 0.84                          |

From the above table, we can get the precision level measurement with the Leica DNA03 digital level. The error per kilometer is 0.84mm, which meets the requirements of the specification.

4.2. Triangular elevation measurement

Using the results of the precision leveling circuit, the elevation is transmitted to the plane control point by the method of photoelectric ranging triangular elevation measurement. The triangular elevation line consists of a precision level point and a GPS network point. It is divided into four areas: the Nauzeri area consists of 10 points, including 1 precision level point and 9 GPS points. The Thotha\Majhhol area consists of 9 points, of which the precision level There are 1 points, 8 GPS outlets; the Chattar
Kalas area consists of 12 points, including 1 precision level point and 11 GPS network points; the Zaminabad area consists of 3 points, including 1 precision level point and 2 GPS points.

The observation was performed automatically using the TCA2003 total station instrument, and the instrument automatically checked the observation limits. During the measurement, the observation data such as temperature, air pressure, station height, and mirror height are recorded, and the data is input into the computer for various corrections. The zenith is observed in the opposite direction, and the four methods are measured.

In order to improve the accuracy of the whole network, the triangular elevation results in the first-level GPS point elevation detection and the measurement results of the encryption control network are unified for the adjustment calculation. The adjustment calculation is carried out by special precision leveling software.

5. Conclusion
In the construction of control network for hydropower hub project in steep mountainous area, the plane control measurement is performed by high-precision dual-frequency GPS receiver instrument. The precision leveling measurement is carried out by the advanced Leica DNA03 digital level. The triangular elevation adopts the advanced TCA2003. The automatic total station is used for observation, the observation method is reasonable, the observation quality is excellent, the internal industry adopts scientific and rigorous method for data analysis and professional software for data processing, which can ensure the accuracy of the control network and achieve economical, fast and efficient results.

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References
[1] GUO Mingming, ZHOU Mingduan, YAN Yue, TIAN Xuedong, LIU Zuqiang. (2010) Study on the Influence Characteristics of Meteorological Correction on Data Processing of GPS Hydraulic Engineering Control Network[J]. Bulletin of Surveying and Mapping, 02: 14-16+55.
[2] Zheng Aijun, Cai Wei, Wang Changsheng. (2018) Research on construction survey control network technology of hydropower station in narrow and long valley area [J]. Hydroelectric power generation, 44 : 70-73.
[3] Gao Xianping. (2018) Realization of Gobi Agricultural Irrigation Water Diversion Control Measurement Technology in Jingtai County [J]. Jingwei Tiandi, 06: 61-62.
[4] Zheng Aijun, Cai Wei, Wang Changsheng. (2018) Research on construction survey control network technology of hydropower station in narrow and long valley area [J]. Hydropower, 08: 70-73.
[5] Fu Kelei. (2018) Using GNSS to control the measurement of water conservancy construction projects [J]. Inner Mongolia Water Resources, 06: 57-58.
[6] Shi Yucheng. (2018) Application of GPS Technology in Channel Measurement [J]. Science & Technology Innovation Review, 35: 87-89.
[7] ZHOU Qingchong. (2008) Research on Some Technical Problems in Xijiang River Channel Measurement [J]. Ocean Mapping, 05: 59-61.
[8] Zhang Longjun. High-precision GPS control network measurement technology for Liuyang-Changsha water diversion project[J]. Engineering Construction, 2006(06): 5-9.
[9] Qiu Bin, He Yueguang. (2001) GPS Control Measurement of Flood Control Project in a County in Karst Area[J]. China Karst, 04: 56-59.
[10] Zhang Shengli, Gao Wenqi, Guo Feng. (2000) Establishment of GPS Control Network for Xianyang-Shaoguan Flood Control Project in Sanmenxia Reservoir Area of the Lower Reaches of the Weihe River[J]. Surveying and Mapping Technology and Equipment, 03: 4-6.