PAK BENG HYDROPOWER PROJECT


KUNMING ENGINEERING CORPORATION LIMITED

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1 OVERVIEW

The Automatic System of Hydrologic Data Collection and Transmission (ASHDCT) is a technical support system to collect and process information of water regime and rain regime in real-time with telemetering, communication and computer techniques and conduct hydrological information forecast in order to achieve the optimized dispatching of flood control, power generation and water supply of water resources and hydropower projects, giving full play to the project benefit.

The Pak Beng HPP is located in Mekong River mainstream in Laos, where is the first cascade of the planning of Lower Mekong River mainstream, of which the dam site is located in the Mekong River mainstream upstream of Pak Beng County town, Oudomax Province, northern Laos, with a drainage area of 218,000km². Mekong River mainstream cascade hydropower stations at its upstream, Laos-Myanmar boundary section, are still in planning stage, the last cascade hydropower station of Lancang River mainstream completed is Jinghong HPP, with the river course distance of about 525km. The precipitation of Lower Mekong River basin is abundant, where rainstorms have various causes with multi-center distribution, and flood characteristics of each control section also has some differences; there are either whole-basin floods or regional ones; the Mekong River Basin above Pak Beng belongs to northern mountain area in Lower Mekong River Basin Zone, with relatively great stream gradient and fast velocity.

Located in the Mekong River mainstream, the Pak Beng HPP has a great flood magnitude and long construction period, so the safety in construction period is particularly important; and in operation period, the ASHDCT can monitor real-time upstream runoff, to enhance the flood control capacity and power generation benefit of the power station. The system shall be conducted according to the demand of Pak Beng HPP in construction period and operation period.

This report determines preliminarily only the system covering range, communication, station location, station number and equipment configuration of each station, proposes preliminarily forecast scheme, power supply, lightning protection, civil engineering design and ways of operation and management and conducts investment estimation.

In specific implementation stages, the detailed implementation design report shall be prepared according to actual conditions.
2 DESIGN BASIS

There is no specification or standard in Laos on ASHDCT, so the overall design of the ASHDCT for Pak Beng HPP shall be implemented as per relevant standards and regulations of China, and main technical basis followed in this design is:

- SL44-2006 Regulation for calculating design flood of water resources and hydropower projects;
- SL250-2000 Standard for hydrological information and hydrological forecasting;
- SL61-2003 Technical specification for hydrologic data collection and transmission system;
- SL199-1997 Regulation for calculating design of communication circuit in hydrological automatic data collection and transmission system;
- SL276-2002 Standard for construction of hydrological fundamental facilities and technical equipment;
- DL/T5051-1996 Design stipulation for automatic system of hydrological data telemetering and forecasting of water conservancy and hydropower projects;

At the same time, other relevant automation standards on hydrological measurement, hydrological forecast and ASHDCT shall also be followed.
3 THE NECESSITY and FEASIBILITY of ASHDCT

(1) Ensure construction safety of the project and collect hydrologic data

The Pak Beng HPP is the first cascade of Mekong River cascade development, of which the construction period is up to 6 years, with a long period. The dam site is about 631km from the Nuozhadu HPP at upstream of Lancang River with multi-year regulation performance, with an interval area of about 73,300km²; about 453km from Guanlei HS, Lancang River boundary control station of China, with an interval area of about 55,000km²; the interval area is very large and the rainfall is very abundant, and the flood formed has a great magnitude and a long lasting time, with great impact on safety spending flood in construction period. To establish the ASHDCT of Pak Beng HPP and conduct flood forecasting in construction period can master fully and timely rain regime, river regime and flood development trend of the river basin above the construction area, to provide the basis helpful for correct decision-making for construction and management, being an important means to ensure safety construction, and is the construction safety and safety spending flood and guarantee the duration.

(2) Ensure safety operation of the project and enhance flood control capability of the hydropower station

Since the flood magnitude of Mekong River mainstream is very great, to construct ASHDCT of Pak Beng HPP for operation period can obtain very accurate hydrological information through hydrological regimen monitoring and forecasting, to arrange real-time and reasonable flood control dispatching measures, enhance flood control capacity of the hydropower station and reduce upstream submergence loss, ensuring safety operation of the hydropower station.

(3) Monitor backwater and reduce impact on national boundary

The backwater of Pak Beng HPP is very long and involves sensitive international issues, and the water level change is quite sensitive to submerging range of the reservoir area. To construct ASHDCT for operation period can monitor conditions of real-time upstream inflow and backwater of reservoir tailrace, to reduce the backwater impact on the national boundary.

In addition, current collection, receiving, processing of hydrological data and hydrological forecasting system and corresponding computer software technology are very mature, applied widely in many domestic and overseas large and medium-sized hydropower stations and water resources systems and obtained good economic and social benefits. For example, the ASHDCT of middle-downstream of Jinsha River hydropower stations (F=78,532km², 8 cascade hydropower stations, F is the coverage area of ASHDCT, the same below), ASHDCT of middle-downstream of Lancang River cascade hydropower stations (101,200km², 14 cascade hydropower stations), ASHDCT of Lixian River cascade hydropower stations (F=9,064km², 7 cascade hydropower stations).
stations), ASHDCT of Nam Ou River cascade hydropower stations in Laos (F=25,495km², 6 cascade hydropower stations) and ASHDCT of Rili River cascade 1 hydropower station in Myanmar (F=3,902km²) undertaken by Kunming Engineering Corporation Limited in recent years; ASHDCT of those hydropower stations have operated successfully, providing a strong support for safety spending flood in construction period and reasonable dispatching in operation period of cascade hydropower stations.

In summary, it is very necessary and feasible to establish the ASHDCT for construction and operation periods of Pak Beng HPP.
4 HYDRO-METEOROLOGICAL NETWORK IN THE BASIN

4.1 STATUS QUO OF HYDRO-METEOROLOGICAL STATION NETWORKS IN THE BASIN

There are lots of Hydrological stations in Lancang - Mekong River basin, there are mainly Yunjinghong HS and Guanlei HS distributed in downstream of Lancang River mainstream, of which the Yunjinghong HS is an important national HS of China with complete and high quality data, and the Guanlei HS is a newly built international flood forecast station of Lancang River; and there are also hydrological stations of Mekong River basin distributed in Thailand, Laos, Cambodia and Vietnam. Among them, SopRuak Gauging Station, Chiang Saen HS, Ban SopKok HS, Chiang Khong Gauging Station are located in Mekong River mainstream in upstream of Pak Beng dam site, of which the Chiang Saen HS has the longest data series, also the design basis station of Pak Beng HPP; and there is the Pak Beng Gauging Station in the county town in downstream of Pak Beng HPP. In 2008, Kunming Engineering Corporation Limited established a special hydrological station in Pak Beng county town to observe water level and carry out discharge measurement; Pak Beng HS hereinafter refers to as the special hydrological station established by Kunming Engineering Corporation Limited unless referred in particular.

There are many precipitation stations distributed in middle-downstream of Lancang River Basin, there are over 3 rainfall observation stations in each county. Precipitation stations distribution in the Mekong River Basin above the dam site of Pak Beng HPP is relatively less, mainly ones of Chiang Rai (Thailand), Chiang Saen (Thailand), Chiang Khong (Thailand), Luang Namtha (Laos), Muang Xay (Laos) and Hougy Xai (Laos). Overview of hydrological and precipitation stations in the drainage basin from Yunjinghong HS to Pak Beng dam site is shown in Table 4.1. Distribution map of hydrological and the precipitation station of Lancang-Mekong River Basin from Yunjinghong HS to Pak Beng Gauging Station is shown in Fig. 4.1.
<table>
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<th>Station Type</th>
<th>Country</th>
<th>Location</th>
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<th>Year to establish station</th>
<th>Item to be measured</th>
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<td>Hydrology</td>
<td>China</td>
<td>Jinghong, China</td>
<td>149.1</td>
<td>1953</td>
<td>Water level, discharge and rainfall, etc.</td>
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<tr>
<td>2</td>
<td>Guanlei</td>
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<td>China</td>
<td>Jinghong, China</td>
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<td>1972</td>
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<td>4</td>
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<td>Chiang Saen County, Thailand</td>
<td>189</td>
<td>1960</td>
<td>Water level, discharge and rainfall, etc.</td>
</tr>
<tr>
<td>5</td>
<td>Sop kok</td>
<td>Hydrology</td>
<td>Thailand</td>
<td>Chiang Saen County, Thailand</td>
<td>201</td>
<td>1972</td>
<td>Water level and discharge</td>
</tr>
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<td>Water Stage</td>
<td>Thailand</td>
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<td>Muang Xay City, Laos</td>
<td></td>
<td>1991</td>
<td>Precipitation</td>
</tr>
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<td>11</td>
<td>Hougy Xai</td>
<td>Rainfall</td>
<td>Lao PDR</td>
<td>Hougy Xai City, Laos</td>
<td></td>
<td>1974</td>
<td>Precipitation</td>
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Fig. 4.1  Distribution map of hydrological and precipitation stations of interval from Yunjinghong to Pak Beng dam site
4.2 STATUS QUO OF ASHDCT

The ASHDCT covering dam site interval from Changdu Hydrological Station to dam site of Ganlanba HPP in Lancang River Basin has been constructed with a catchment area of about 101,200km², covered ASHDCT, covering all cascade hydropower stations from Changdu to Ganlanba interval, where there are 153 telemetering stations arranged in the system, of which there are 125 precipitation stations and 57 hydrological and gauging stations (part of them with rainfall observation); this ASHDCT has been put into operation in February 2007, operated safely for 8 years already, providing a strong support for safety spending flood in construction period and reasonable dispatching in operation period of cascade hydropower stations in middle-downstream of Lancang River.

In order to find out hydrological condition of each control section of Mekong mainstream, MRC Secretariat has arranged a forecasting station network covering 24 hydrological stations in Mekong mainstream (including Yunjinghong Station and Man'an Station of China) to conduct water level monitoring and flood forecasting, of which this hydrological information forecasting station network can forecast the level of each station for next 5 days, to be able to deduce the discharge of each station for next 5 days through the stage-discharge relation of each hydrological station, and forecast results are published on the website of MRC Secretariat, updated daily in flood seasons and weekly in dry seasons. In this forecasting station network, what located in upstream mainstream of Pak Beng dam site are Yunjinghong HS of China and Chiang Saen HS of Thailand, of which Chiang Saen HS is the nearest to Pak Beng dam site, however, the area of the interval from Chiang Saen HS to Pak Beng is 29,000 km², with many tributaries, the flood forecasting frequency and accuracy of hydrological stations are far from requirements of hydrological data collection and transmission in construction period and operation period of Pak Beng HPP.

In order to meet the need of carrying out feasibility study design for MOU of Pak Beng HPP of Laos, Kunming Engineering Corporation Limited established a special hydrological station from the complex Pak Beng HPP to Pak Beng county town in 2008, including four groups of gauging stations, water gauge numbers are A, B, C and D respectively from upstream to downstream, of which the water gauge A and B are located in upstream and downstream of the dam site respectively. The position map of four gaugeing stations is shown in Fig. 4.2.
There is no human living nearby water gauges A and B of Pak Beng special hydrological station, so the self-recording gauge is adopted for water level observation, and both manual water gauge and self-recording gauge are adopted for C and D jointly for water level observation. Regular observation mode shall be set for the self-recording gauge, increasing measuring times when water level changing amplitude become great; with the self-recording water gauge, the observation is once every hour in flood seasons and once every two hours in dry seasons and with manual water gauge, the observation is three times daily in dry seasons, timed observation at 8:00, 14:00 and 20:00 for checking the water level observed by self-recording gauge water level; discharge measurement is carried out nearby the gauge D, by flood season and dry season annually; up to the end of 2013, there are total 246 measurements, with the discharge range of 793m³/s~7,290m³/s.

The four gauging stations can be used continuously at the later stage as basic stations of ASHDCT of this hydropower station.
5 Design Ideas and Principles

Pak Beng HPP is located in the Mekong mainstream, of which the reservoir backwater flows to the border of Laos and Thailand; there is no upstream hydropower station linked, it links Luang Prabang HPP downstream, but two stations belong to different investing owners; though the Sanakham HPP in middle stream of Mekong and Pak Beng HPP belong to the same owner, the two cascade hydropower stations are far apart, and there are Luang Prabang and Sainyabuli HPPs located between them, therefore, the ASHDCT of Pak Beng HPP is considered provisionally as an independent system.

The design of the ASHDCT of Pak Beng HPP obeys following principles:

- The drainage basin above dam site of this hydropower station is involved in four countries, if the station network is arranged uniformly, installation, communication and maintenance of the telemeter station will involve very complex international issues, being difficult to coordinate; considered rainfall distribution in the drainage basin and important role of hydrological (gauging) stations in this data collection and transmission system, the arrangement this time of mainstream hydrological (gauging) station network of ASHDCT shall be based on the Laos inland as much as possible to reduce customs formalities for patrol inspecting and gauging; and precipitation stations can be arranged in Laos and Thailand and even Myanmar subject to demands, and the Employer is responsible for communication and consultation with Thailand and Myanmar when implementing specifically.

- Existing stations and sites shall be used as far as possible when arranging sites, to ensure the continuity of hydrological data and reduce investment.

- Permanent stations and sites shall be combined with temporary ones, convenient for turning temporary stations and sites in construction period into permanent ones in operating period; meanwhile, conduct construction following the principle of being convenient for construction and maintenance management.

- The uniform construction design shall be conducted following the principle of being favor of environmental protection and water and soil conservation.

- Conduct construction following the principle of the overall planning of drainage basin, being economic and practical, advanced and reliable, convenient to construct, maintain and manage.

According to the planning, the Lower Mekong River Basin is divided into eleven cascade development projects: Pak Beng, Luang Prabang, Sayaboury, Pak-Lay, Sanakham, Pa Mong, Ban Koum, Phou Ngoy, Don Sahong, Stung Treng and Sambor HPPs. According to current development of all hydropower stations, Pak Beng, Sayaboury, Sanakham and Don Sahong HPPs and have been commenced to construct, and the remaining hydropower stations are in the early research stage. Along with progress of hydropower station development, each hydropower station needs to construct an ASHDCT in the future; considered for long-term, it
is recommended that the planning of ASHDCT of hydropower stations of Lower Mekong Basin shall follow following principles:

- **Regional overall consideration and unified planning.** Conducting a unified planning and overall consideration for the ASHDCT of cascade, to arrange reasonably telemeter stations and sites and configure reasonably forecasting model, developers of cascade hydropower stations can invest to construct according to the proportion of stations and sites arrangement accounting for entire drainage basin cascade.

- **Share resources and information to avoid redundant construction.** At present, the ASHDCT has been constructed for some hydropower stations within the drainage basin, for which resources and information shall be shared for considerations of saving resources and avoiding redundant construction.
6 FUNCTION AND MAJOR TECHNICAL INDEXES OF ASHDCT

6.1 FUNCTION OF THE SYSTEM

6.1.1 Basic function and extended function of the system

According to different applications, system functions are divided mainly into basic function, extended function and alarm/monitoring function.

(1) Basic function

The basic function refers to the function that the system shall have, including following:

- Collection and transmission function

  It is able to acquire automatically, transmit and receive fast real-time water regime elements including rainfall and water level of each telemeter station under severe weathers such as extraordinary rainstorm and whole gale. The meaning of "real-time" here refers to once changing one specified amplitude of hydrological elements for self-reporting system, i.e., once transmission and receiving, and once interrogation of central station for query-reply system, i.e., once transmission and receiving, and the telemeter station itself will acquire once for each changing of one unit according to the resolution of sensors, regardless of the system. And, it has the function of documenting the time mark and converting communication mode automatically.

- Storage function

  The telemeter station shall have sufficient storage capacity, and the storage capacity is generally information content of 90, 180 and 360 days respectively, with a redundancy of 15 to 30 days.

- Data processing function

  The central station shall have the hydrological data processing function, including checking, error correcting, interpolating, classifying and formatting process on data received, documenting receiving time mark, establishing calculation table and database, querying and retrieving data, displaying, printing and drawing hydrological data chart.

  It is able to query regularly or manually the water level, rainfall data and working status of subordinate stations. It is able to transmit water level and rainfall records by batch at specified periods.

  It is able to access LAN or WAN to achieve data sharing.

  It has the function to transmit hydrological information to each cascade hydropower station and relevant authorizes outside of the system.

  It has the data maintenance function of security and confidentiality, providing data backup to ensure data security.

- Hydrological forecasting function
It has functions of automatically completing forecast with different schemes and controlling software running through man-machine conversation, and can forecast in the case of telemeter information missing.

It includes flood forecast parameter initialization, parameter setting/modify, timing forecast, off-line estimating forecast, result storage, printing and output.

**Backup communication function**

The telemeter station that maintenance personnel cannot access and repair the fault within a short time, particularly important station in the system, shall have backup communication function. According to local communication conditions, the backup trunk line, cable telephone, wireless telephone, public data network, satellite communication and other network tools can be used as the backup communication.

**Protection function**

The over voltage protection shall be conducted for both telemeter station and central station, so that the equipment cannot be easy to be damaged by lightning stroke.

(2) **Extended function**

According to requirements of the design, the central station shall have the function of receiving and processing water information telegraph and data and information transmitted by other collection and transmission system and incorporating into own collection and transmission system through telegraph text translation and format converting; the system is extensible for middle/long term runoff forecasting; and the system is able to be expanded with reservoir operation function.

(3) **Alarm /monitoring function**

- **Hydrological elements off-limit alarm**
  
  It will send an alarm immediately when rainfall or water level, discharge, etc., exceed a specified value.

- **Insufficient power supply alarm**
  
  It will send an alarm immediately when power supply of equipment is insufficient, particularly power capacity of the telemeter station or relay station is lower than the threshold value set.

- **Equipment accident alarm**
  
  It will send an alarm automatically immediately when any equipment accident occurs.

  In order to attract timely attention of the staff, audible and visual alarm ways can be used in addition to the screen display alarm.

- **Correcting the clock and switch on/off machine of the telemeter station.**
6.1.2 FUNCTION SELECTION PRINCIPLE

- It must have the basic function and alarm/monitoring function of the collection and transmission system;
- The extended functions shall be determined through comprehensive comparison and analysis on factors of engineering environment conditions, requirements on automation and reliability of the collection and transmission system, as well as the investment, equipment conditions.

6.2 MAJOR TECHNICAL INDEXES OF THE SYSTEM

(1) Response speed

The operation time to complete once acquiring, processing and forecasting of all hydrological elements in the drainage basin shall not exceed 20min.

(2) The collection and transmission accuracy of system

- The collection accuracy of hydrological elements shall reach the regulation in Table 6.2-1.
- The qualified rate of main hydrological forecasting scheme shall be not less than 70%, or, the certainty coefficient shall be greater than 0.70.

<table>
<thead>
<tr>
<th>Hydrological elements</th>
<th>Collection resolution</th>
<th>Allowance error</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td>0.5mm</td>
<td>≤±4%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0mm</td>
<td>≤±4%</td>
<td></td>
</tr>
<tr>
<td>Stage</td>
<td>1.0cm</td>
<td>95% of measuring point shall not exceed 2cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>99% of measuring point shall not exceed 3cm</td>
<td></td>
</tr>
<tr>
<td>Gate level gauge</td>
<td>1.0cm</td>
<td>95% of measuring point shall not exceed 2cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>99% of measuring point shall not exceed 3cm</td>
<td></td>
</tr>
</tbody>
</table>

(3) Reliability index of the system

- The Mean Time Between Failures (MTBF) of the telemeter station and central station equipment shall be greater than 6300h;
- The telemeter station with average monthly normal operation rate of system data collection reaching average over 95% (the important control station must be included) can transmit data accurately to the central station. The completion rate of data processing
operation shall be greater than 95%;

- The equipment availability of ASHDCT shall be greater than 90%, and the ASHDCT shall not interrupt the forecasting in heavy rainfall.

(4) Normal work indexes of equipment of the data collection and transmission system

The equipment of data collection and transmission system shall be able to work normally under conditions specified in Table 6.2-2.

**Table 6.2-2 Normal working environment of equipment**

<table>
<thead>
<tr>
<th>Device name</th>
<th>Temperature(°C)</th>
<th>Relative humidity(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment of central station</td>
<td>+5~+40</td>
<td>≤90</td>
</tr>
<tr>
<td>Indoor equipment of the telemeter station</td>
<td>−10~+45</td>
<td>≤90</td>
</tr>
<tr>
<td>Sensors and outdoor equipment of the telemeter precipitation station</td>
<td>0~50</td>
<td>≤95</td>
</tr>
<tr>
<td>Sensors and outdoor equipment of the telemeter gauging station</td>
<td>−10~50</td>
<td>≤95</td>
</tr>
</tbody>
</table>
7 FORECAST SCHEME AND NETWORK

7.1 SYSTEM COVERING

Pak Beng HPP is the first of cascade development of Mekong River mainstream, and there are Nuozhadu, Jinghong and Ganlanba HPPs in Lancang River mainstream, its upstream. There are mainly Yunjinghong, Guanlei, Chiang Saen, Ban SopKok and Chiang Khong hydrological (gauging) stations above Pak Beng dam site, of which the Guanlei HS is the boundary control station of Lancang River, and also the outlet control station of ASHDCT of Lancang River cascade hydropower stations. As the boundary control station of Lancang River, Guanlei controls 75% of drainage basin area and 67% of inflow of Pak Beng dam site, and the forecast period taking this station as the inflow control station is about 45 hours; Chiang Saen HS is an important one in Mekong mainstream, by which the drainage area controlled accounts for 86.7% of Pak Beng, and the inflow controlled accounts for about 85.4% of Pak Beng, with a forecast period of about 19 hours. Combined with the dam above the basin runoff, flood characteristics, and hydrological stations in the distribution and engineering characteristics factors. At the beginning of the proposed north of this station during construction period of hydrological measuring and reporting system coverage for closing tired hydrological station to north of the dam section.

The drainage basin area of this interval is 55,000km², the rainfall of the interval drainage basin is great and derived tributaries are many, of which Nanlew River (Myanmar), Nam Ing (Thailand), Nam Kok (Thailand) and Nam Tha (Laos) are four larger tributaries in the interval. The dam section from Chiang Saen to the dam site in this region is key monitoring area, with an interval area of about 29,000km², and river course distance of about 185km, main tributaries in the interval are Nam Ing (Thailand), Nam Kok (Thailand), Nam Tha (Laos) and Nam Ngum (Laos), and so on.

7.2 CONFIGURATION OF HYDROLOGICAL FORECAST SCHEME

7.2.1 Overall Configuration of Hydrological Forecast Scheme

According to requirements of Pak Beng HPP in different construction period, the ASHDCT of Pak Beng HPP is divided into construction period and operation period, of which stations shall be updated or supplemented for the station network arrangement of operation period based on the station network in construction period; and scheme configuration of operation period forecast shall be based on the forecast scheme of construction period and model parameters shall be calibrated and corrected according to data accumulation in construction period.

The area above the dam site of Pak Beng HPP involves four countries: China, Myanmar, Thailand and Laos; as one of international rivers, the Lancang - Mekong River acts as the boundary river of Myanmar–Laos and Thailand ~Laos respectively, most of which goes crossing sparsely populated, rain forest covered mountain, with very inconvenient traffic. There are Yunjinghong HS and Guanlei HS of China and Chiang Saen HS of Thailand, all those telemeter stations with high accuracy control the vast majority of drainage basin above
the dam site; Dam to the upstream off tired interval basin on the right bank is located in Myanmar, Thailand, the interval in the Mekong River Basin semi humid and semi-arid region, relatively flat terrain, the range of little runoff, and on the left in Laos, the region close to the center of rainstorm of the Mekong River Basin, the area between the runoff is relatively large.

Considered synthetically engineering location of the hydropower station, characteristics of rainfall runoff of the drainage basin and distribution characteristics of precipitation stations and hydrological stations in the drainage basin, the ASHDC of Pak Beng HPP is proposed preliminarily to be composed of the river system forecasting based on hydrological stations in Lancang - Mekong River mainstream and rainfall runoff forecasting based on interval precipitation stations.

(1) River system forecasting

River system forecasting is a forecasting method to forecast water level and discharge of downstream cross section according to ones of upstream section, used mostly in the drainage basin with larger catchment area. River system forecasting mainly includes corresponding water level (discharge) forecasting, combined discharge forecast method and flow algorithms method. Corresponding water level (discharge) forecasting is mainly applicable to the tributary-free river reach or the reach with tributaries with small water volume, and combined discharge forecast method and flow algorithms method are mainly applicable to the reach with tributaries with great inflow.

Corresponding water level (discharge) forecasting method is to forecast on the basis of analyzing the change law of quantitative relationship between a great number of synchronous phase levels (discharge) of upstream and downstream section water level (discharge) hydrographs measured in the reach and the propagation velocity and then establishing empirical correlation relationship.

The combined discharge forecast method is to add up corresponding discharges of mainstream hydrological stations and tributary hydrological stations in the reach with tributaries converging into as per the time propagating to next station, to express that the discharge combined can reach next station simultaneously so as to establish the correlation diagram of the discharge combined and the corresponding water level of next station (discharge) to conduct forecasting.

Flow algorithms method is the method to calculate the inflow discharge process of reach upstream section into outflow discharge process of reach downstream section based on the principle of water volume balance of the reach and storage - discharge relation, such as the characteristic river-length method and Muskingum method.

For this project, the forecasting relation can be expressed as:

\[ Q_{\text{Pak Beng } t+\tau} = f(Q_{\text{hydrometric station}}, t) \]

Where: \( Q_{\text{Pak Beng } t+\tau} \) — Pak Beng \( t+\tau \) + time discharge, \( m^3/s; \)
\( Q \) based on \( \tau \)—Based on station \( t \) discharge value, \( m^3/s \);

\( \tau \)—Flood propagation time, h.

(2) Model of rainfall runoff forecasting

Forecasting runoff processes of the river course and reservoir station (point) according to the rainfall in the drainage basin, the rainfall runoff forecasting is mainly used to control the flood forecasting in the hydrological station interval. According to available successful cases of the Kunming Engineering Corporation Limited, for the rainfall runoff forecasting of ASHDCT of this project, the following several schemes are mainly adopted:

a. \( P\sim Pa\sim R \) rainfall runoff forecasting scheme

In the rainfall runoff producing forecasting, what is used mostly and successfully is mainly \( P\sim Pa\sim R \) rainfall runoff empirical correlation diagram. The rainfall runoff empirical correlation diagram is a kind of quantitative correlation diagram established with catchment averaged rainfall of each rainfall and total runoff volume generated correspondingly and main factors impacting them on the basis of combination of cause analysis with statistical correlation, of which the commonly used is \( P\sim Pa\sim R \) empirical correlation diagram. Proved through the flood forecasting practice of multiple projects, this method has advantages of simple application, reliable accuracy and being easy to combine with experience of experts to conduct correction.

Main parameters of the \( P\sim Pa\sim R \) empirical correlation diagram are precipitation \( P \), runoff depth \( R \) and the antecedent impact precipitation \( Pa \), and parameters impacting \( Pa \) are maximum soil water shortage \( Im \) and the daily regression coefficient of soil water content \( k \).

Unit hydrograph method is mainly used for rainfall concentration forecasting. The unit hydrograph method used commonly refers to the ground runoff unit hydrograph analyzed according to hydrological data, of which unit net rainfall depth is generally taken 10mm, and unit hydrograph is mainly determined on the basis of drainage basin characteristics, generally taking 3h, 6h, etc.

This forecasting scheme is being in forecasting schemes of ASHDCTs of Jinsha River cascade hydropower stations, middle / downstream of Lancang River cascade hydropower stations and Nam Ou cascade hydropower stations.

b. Xin'anjiang model

The Xin'anjiang model is a hydrological model proposed by Zhao Renjun in Hohai University suitable for humid and semi-humid regions, which has been widely applied in hydrological modeling and forecasting after being tested and modified continuously in practice.
The Xin'anjiang model is a conceptual rainfall runoff model, which has the ability of distributed process, being able to use to simulate runoff producing and concentration in catchment slope surface of humid and semi-humid regions. Overall structure of the Xin'anjiang model can be divided into three parts: runoff producing calculation, dividing water source and runoff concentration. Three of them are essentially independent each other. The runoff volume is calculated with the rainfall, evaporation and soil water content. With the simulation method of free water storage volume, the runoff volume is divided into three water sources of the surface water, interflow and groundwater. Because of different mediums that water goes through during concentration process, three kinds of water sources have different runoff concentration characteristics. The runoff concentration process can be divided into three stages, i.e., the slope surface runoff concentration of the unit area, the river network runoff concentration of unit area and river course runoff concentration from the unit area outlet to the control station of drainage basin outlet. Different simulation methods are used for different runoff concentration processes.

Fig. 7.2-1  Structure diagram of the Xin'anjiang model
- Calculation of evapotranspiration
  The three-layer calculation model is used for the calculation of evapotranspiration in the Xin'anjiang (three water sources) model, of which the input is the measured water surface evaporation of the evaporator, converted into evapotranspiration capacity of the drainage basin with the conversion coefficient K then. The evapotranspiration process is described with the change process of tension water storage capacity (WM) is used to evapotranspiration, of which the water storage capacity is divided into upper, middle and lower three layers (WUM, WLM, WDM, WM=WUM+WLM+WDM).

- Calculation of runoff producing
  The theory of runoff formation on repletion of storage is used for the calculation of runoff producing. The so-called runoff formation on repletion of storage is that, the runoff produces after water content of aeration zone reaches the field capacity, and the runoff will not produce before water content of aeration zone reaches the field capacity and entire rainfall will be absorbed by the soil to become tension water.

- Water sources dividing
  A free water storage reservoir is used for water sources dividing in the Xin'anjiang (three water sources) model, of which two outlets are set for the free water storage reservoir, and outflow coefficients are KI and KG respectively. Runoff producing volume R enters the free water reservoir, and the runoff is divided into surface runoff (RS), interflow runoff (RI) and groundwater runoff (RG) through the mode of two outflow coefficients and the overflow.

- Calculation of runoff concentration
  The calculation of runoff concentration in unit area includes two runoff concentration stages of slope and river network.
  Slope runoff concentration refers to the water concentration process on slope surface. In this runoff concentration stage, water flow has not only horizontal movement, but also vertical movement. On drainage basin slope, regulating-storing function of surface runoff is not large, the regulating-storing on underground runoff is large, and the interflow runoff is between the two. The river network runoff concentration refers to the runoff concentration process of water flow along the river network after enters the channel continuously from slope surface. In the stage of river network runoff concentration, the runoff concentration characteristics is subject to hydraulics conditions of the channel, all kinds of water sources are consistent.

This model has been applied in forecasting schemes of ASHDCTs of Lixian River cascade hydropower stations and Ruili River Cascade I Hydropower Station, achieved good effect.

For this project, the river system forecasting method is mainly used for Mekong River mainstream, and rainfall runoff forecasting method is mainly used for the interval and larger tributaries. What needed to explain is that, the forecast scheme configuration of the ASHDCT
is the process to conduct calibration of model parameters, being modified gradually, needing to be based on certain data accumulation; and previous forecasting accuracy is relatively low, and the forecasting accuracy will rise gradually in later stages with data accumulation and parameters correction. According to available cases and experience of Kunming Engineering Corporation Limited in regions with similar conditions, the model above can meet the demand of this project; in view of that the model parameters calibration requires certain data accumulation and certain time calibration and validation, it is recommended to implement construction of telemeter stations of this ASHDCT and preparation of forecasting schemes as soon as possible.

7.2.2 Forecast Scheme in Construction Period

Hydrological forecasting objects of Pak Beng HPP during construction period are water level and discharge of inlet and the outlet of diversion tunnel, to meet the demand of forecasting, dispatching and decision-making for construction flood control; for flood forecasting, the effective forecast period shall be increased as far as possible to achieve the initiative for flood control work; and forecasting results shall be inspected compared to measured data, to perfect continuously in implementation process, improving forecast accuracy.

According to arrangement of station network in Lancang -Mekong River Basin, different hydrological stations are taken as the forecasting inflow control stations, which can provide discharge forecasting in flood and dry seasons with different forecast periods for Pak Beng HPP.

(1) Discharge forecasting scheme with a forecast period of about 45h

Taking Guanlei HS as the forecasting inflow control station, the forecast period for this forecast is about 45h; the forecast period of this forecasting scheme is very long, and forecast results can be corrected through hydrological (gauging) stations established in the middle of the reach level by level, to improve the forecasting accuracy.

Catchment area of Guanlei HS is 163,000km², accounting for 74.8% of the basin area (F=218,000km²) controlled by the dam site, and average annual discharge accounts for 67.4%; Guanlei HS is taken as the forecasting inflow control station and Pak Beng HS as the outflow control station, and the river system forecasting scheme is used to forecast the discharge of Pak Beng dam site.

The forecasting relation is:

\[ Q_{\text{Pak Beng } t+\tau} = f (Q_{\text{Guanlei } t}) \]

Where: \( Q_{\text{Pak Beng } t+\tau} \) —Pak Beng \( t+\tau \) + time discharge, \( \text{m}^3/\text{s} \);

\( Q_{\text{Guanlei } t} \) —Guanlei Station \( t \) discharge value, \( \text{m}^3/\text{s} \);

\( \tau \) —Flood propagation time, h.

There are data from 1972 ~ 1987 in Yunjinghong HS, Chiang Saen HS and Ban SopKok HS, discharge factors of responsiveness and propagation time can be analyzed according to daily average discharge series of these three stations to calibrate
preliminarily parameters of river system forecasting, conducting analysis and calibration in later stages based on measured data of this system to improve the forecasting accuracy.

Fig. 7.2-2   Comparison chart for average daily discharge process of Yunjinghong Station, Chiang Saen Station and Ban Sop Kok Station

What needed to explain is that, in the interval between Guanlei and Pak Beng, the area is large, the latitude spanned is much, and the flood forming reasons are various, with not only entire drainage basin flood, but also interval flood. Such as the flood in 1966 and 2007 at Yunjinghong Station and Chiang Saen Station, the flood in 1966 isentire drainage basin one, and the responsiveness of entire flood period is very good; and flood in 2007 is mainly large in the interval from Yunjinghong to Chiang Saen, and flood responsiveness of flood period is worse than the one in 1966. In order to improve the accuracy of river system forecasting, hydrological stations can be established in mainstream according to the demand to correct forecasting results in real-time.
For this system, tour gauging stations including Ban Xieng Kok HS, Ban Tung Station (the opposite bank of Chiang Saen HS at Laos side) and Hougy Xai HS (the opposite bank of Chiang Khong HS, at Laos side) are proposed to construct in the interval between Guanlei HS and Pak Beng dam site, and these stations can be used to calibrate forecasting results level by level, to achieve the goal of improving the accuracy of dam site discharge forecasting.

(2) Discharge forecasting scheme with a forecast period of about 18h~12h

Water level and discharge at Pak Beng dam site are forecast with the discharge of Hougy Xai plus discharged flows of dam sites of Cascade I hydropower stations of Nam Kok River, Nam Ing, Nam Ngam River and Nam Tha River, forecast periods of this forecast scheme are respectively 18h and 12h, the accuracy of this forecast scheme is relatively high. For Nam Ing, Nam Kok River, Nam Ngam River and Nam Tha River Basin, the discharge of own tributary is forecast with rainfall runoff, combined with mainstream forecast results, to forecast discharge and water level of design section.

The forecasting relation is: $Q_{Pak\ Beng\ t+\tau} = f(Q_{based\ on\ t}) + f(Q_{Nam\ Ngam\ t1}, Q_{Mae\ Nam\ Kok\ t2}, Q_{Mae\ Nam\ Yam\ t3}, Q_{Namtha\ t4}) + f(P\ zone, E\ zone,...)$

Where: $Q_{Pak\ Beng\ t+\tau}$—Pak Beng $t+\tau$ time discharge, m$^3$/s;

$Q_{based\ on\ t}$—$t$ time discharge value of Ban Tung Station or Hougy Xai Station, m$^3$/s;

$Q_{XX\ t}$—Discharge of XX River when combining discharge with mainstream at $t$ time, m$^3$/s;

Zone $P$—Interval precipitation, mm;

Zone $E$—Evaporation of uncontrolled interval, mm;

$\tau$—Flood propagation time, h.

According to the experience of Kunming Engineering Corporation Limited and hydropower construction units of China, when overproof flood occurs, a 2h forecast period can meet the need of safe evacuation of personnel, 6-hour one can meet the need of safe evacuation of important machinery and equipment and 12-hour one can meet the need of
transferring important construction material, so forecast periods of both two schemes mentioned above can meet evacuation and transfer of personnel, important machinery and equipment and construction materials when overproof flood occurs.

The forecast range of ASHDCT of middle /downstream of Lancang River is the interval between Changdu and Jinghong, if necessary, the forecasting of the discharge at Guanlei Station or Yunjinghong Station in Lancang River can access the ASHDCT of Pak Beng HPP to lengthen the forecast period further.

Because the flood in Mekong River is huge, and also in the dry season, in order to guarantee the safty in the construction period, some safty measures should be done before the construction:

a. Establish the automatic hydrological system and forecasting the discharge at certain section as early apossible, which can collected real time data to calibrate the parameters of the model.

b. Establish good communication and coordination mechanism with the Lancang River Hydropower Development Co., Ltd, which can obtain the hydrology regime and operation regulation of the uperstream HPP.

c. Some planning should be made to deal with the flood above the standards, which can guarantee the important equipment and building avoiding destroying.

7.2.3 Forecast Scheme in Operation Period

The reservoir tail area of Pak Beng HPP involves very sensitive objects, in order to reduce the backwater impact of Pak Beng HPP on KengphaDai, real-time monitoring of tailrace of reservoir tail is required; meanwhile, according to the operation dispatching and analysis on the impact on downstream, the dam front water level and dam downstream water level are required to forecast.

For operation of Pak Beng HPP, main forecast is the level of reservoir tail KengphaDai, reservoir inflow, dam front water level, and monitoring of approach channel level and water level under the dam. The flood propagation time is shortened because the characteristics of channel in reservoir area of the hydropower station have some change when Pak Beng HPP is operating. However, Pak Beng HPP is a river course type reservoir, reservoir will not bring great change to runoff producing and concentration conditions of drainage basin after storing water, the forecast scheme for construction period can be used basically, but considering the forecast period of ASHDCT in operation period is shorter than that in construction period, the hydropower station operation dispatching demand and requirements to provide hydrological information for downstream, it is required to conduct parameters correction of forecast scheme according to data of operation period to improve forecast accuracy, and the forecast scheme of operation period shall be reprepared if necessary.

7.3 NETWORK

According to requirements for configuration of hydrologic forecast schemes in construction
period and operation period, there are 27 telemeter stations and 12 telemeter hydrological (gauging) stations arranged for ASHDCT of Pak Beng HPP, of which 7 tour gauging stations are precipitation station concurrently; and 15 telemeter precipitation stations, of which 6 are in Thailand and 9 in Laos. The station network arrangement of the ASHDCT of Pak Beng HPP is shown in Table 7.3, and station network distribution map is shown in Fig. 7.3.

<table>
<thead>
<tr>
<th>No.</th>
<th>River</th>
<th>Station</th>
<th>Country</th>
<th>Location</th>
<th>Item of hydrologic data</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mainstr.</td>
<td>Guanlei</td>
<td>China</td>
<td>Guanlei HS</td>
<td>H, Q (Constructed)</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Ban Xieng Kok</td>
<td>Lao</td>
<td>Ban Xieng Kok Village</td>
<td>H, Q (Constructed newly)</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Ban Tung</td>
<td>Lao</td>
<td>Ban Tung Village (the opposite of Chiang Saen HS)</td>
<td>H, Q, P (Constructed newly)</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Hougy Xai</td>
<td>Lao</td>
<td>Hougy Xai (the opposite of Chiang Khong HS)</td>
<td>H, Q, P (Constructed newly)</td>
</tr>
<tr>
<td>5</td>
<td>Mainstr.</td>
<td>Upper cofferdam station (Water gauge A)</td>
<td>Lao</td>
<td>Upper and lower cofferdams of Pak Beng dam site</td>
<td>H, P (Constructed)</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Lower cofferdam station (Water gauge B)</td>
<td>Lao</td>
<td>Lower cofferdam of Pak Beng dam site</td>
<td>H, Q (Constructed)</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>KengphaDai</td>
<td>Lao</td>
<td>Laos - Thailand border</td>
<td>H, P (Constructed newly)</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Water gauge C</td>
<td>Lao</td>
<td>Between county town and the lower cofferdam</td>
<td>H, Q (Constructed)</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Pak Beng (Water gauge D)</td>
<td>Lao</td>
<td>Pak Beng County town</td>
<td>H, Q (Constructed)</td>
</tr>
<tr>
<td>10</td>
<td>Branches</td>
<td>Chiang Rai</td>
<td>Thailand</td>
<td>Chiang Rai Station of Nam Kok</td>
<td>H, Q, P (Constructed)</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>Thoeng</td>
<td>Thailand</td>
<td>Thoeng Station of Nam Ing</td>
<td>H, Q, P (Constructed)</td>
</tr>
<tr>
<td>12</td>
<td>Nam Tha</td>
<td>Lao</td>
<td>Downstream of Nam Tha 1#</td>
<td>H, Q, P (Constructed newly)</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Nam Ngam</td>
<td>Ban Nam Ou</td>
<td>Lao</td>
<td>Ban Nam Ou Village</td>
<td>P (Constructed newly)</td>
</tr>
<tr>
<td>14</td>
<td>Namtha Gang</td>
<td>Lao</td>
<td>Namtha Gang Village</td>
<td>P (Constructed newly)</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>Ban Ta Pha</td>
<td>Lao</td>
<td>Ban Ta Pha Village</td>
<td>P (Constructed newly)</td>
</tr>
<tr>
<td>16</td>
<td>Namtha</td>
<td>Louang Namtha</td>
<td>Lao</td>
<td>Louang Namtha County</td>
<td>P(Constructed newly)</td>
</tr>
<tr>
<td>17</td>
<td>Mainstr.</td>
<td>Ban Nali</td>
<td>Lao</td>
<td>Ban Nali Village</td>
<td>P(Constructed newly)</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>Ban Hom</td>
<td>Lao</td>
<td>Ban Hom Village</td>
<td>P(Constructed newly)</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>Ban Pho</td>
<td>Lao</td>
<td>Ban Pho Village</td>
<td>P(Constructed newly)</td>
</tr>
<tr>
<td>20</td>
<td>Mainstr.</td>
<td>Prap Khop</td>
<td>Lao</td>
<td>Prap Khop Ben Village</td>
<td>P (Constructed newly)</td>
</tr>
<tr>
<td>21</td>
<td></td>
<td>Kong Ban</td>
<td>Lao</td>
<td>Kong Ban Village</td>
<td>P(Constructed newly)</td>
</tr>
<tr>
<td>22</td>
<td>Mae Nam Kok</td>
<td>Tha Tum</td>
<td>Thailand</td>
<td>Tha Tum Village</td>
<td>P(Constructed newly)</td>
</tr>
<tr>
<td>23</td>
<td>Mae Nam Kok</td>
<td>Mae Chan</td>
<td>Thailand</td>
<td>Mae Chan Village</td>
<td>P (Constructed newly)</td>
</tr>
<tr>
<td>24</td>
<td>Mae Nam Yam</td>
<td>Bang Tau</td>
<td>Thailand</td>
<td>Bang Tau Village</td>
<td>P(Constructed newly)</td>
</tr>
<tr>
<td>25</td>
<td>Mae Nam Yam</td>
<td>Ban Chien</td>
<td>Thailand</td>
<td>Ban Chien Village</td>
<td>P (Constructed newly)</td>
</tr>
<tr>
<td>26</td>
<td></td>
<td>Mangray</td>
<td>Thailand</td>
<td>Mangray Village</td>
<td>P (Constructed newly)</td>
</tr>
<tr>
<td>27</td>
<td></td>
<td>Phayao</td>
<td>Thailand</td>
<td>Phayao Village</td>
<td>P (Constructed newly)</td>
</tr>
</tbody>
</table>
Among stations above, the Guanlei, Ban Xieng Kok, Ban Tung Station, Hougy Xai and Pak Beng HS forecast mainly the water level and discharge of mainstream; in the river system forecasting scheme, the Guanlei acts as the inflow control station, the water level and discharge of Pak Beng HS (4 groups of water gauges) are forecast objects, and forecasting results are conducted real-time correction with measured the discharge of rest stations. As tributary forecast stations, Chiang Rai Station, Thoeng Station and Nam Tha Station forecast mainly the discharge of Nam Ing, Nam Kok and Nan Tha. Precipitation stations in each tributary are mainly used for monitoring precipitation of tributaries; the precipitation runoff forecast model is used to forecast discharge of the tributary, where there is no hydrological station arranged in the Nam Ngam River, so parameters of Nam Tha forecast model can be used as parameters of rainfall runoff model of this drainage basin.

According to forecast demand, discharge measurement is required to conduct at Ban Xieng Kok Station, Chiang Rai Station, Thoeng Station, Ban Tung Station, Hougy Xai Station, Nam Tha Station and Water Gauge D to calibrate stage-discharge relation, forecasting the discharge of design section.

Among stations above, the Guanlei Station, Chiang Rai Station and Thoeng Station are existing ones, needing to improve or increase equipment; there have been four groups of water gauges as existing sites, being able to directly incorporate into this system; and the rest of stations and sites are currently considered as ones established newly.

For stations and sites above, in addition to that the upper cofferdam station has no function due to water storage in operation period, basically, all the rest can be used continuously in operation period, of which the lower cofferdam station can act as a outlet one flowing out of the reservoir, and water gauge C and D can be used to monitor water level amplitude at the downstream gauging station in operation period; according to demand, on the basis of stations and sites above during operation period, gauging stations on the dam and at the entrance and exit of the approach channel are also required to construct to monitor the water level at the dam and approach channel.

The rainfall runoff forecast model in this design is mainly used in the interval between Chiang Saen and Pak Beng, with an interval area of 29,000 km²; considered the sparsely populated interval with inconvenient traffic, there are only 22 precipitation stations arranged in this system (including hydrological station, measuring precipitation concurrently), with a low density of stations and sites, average 1,318 km²/station. In late stage, stations and sites can supplemented appropriately if needed to meet the demand of forecasting.
Fig. 7.3  Diagram of station network arrangement for ASHDCT of Pak Beng HPP
8 COMMUNICATION

8.1 COMMUNICATION MODE

With rapid development of modern communication technology, communication modes including the satellite, public communication (GSM short message), GPRS and program-controlled telephone (PSTN), etc., have been widely applied in ASHDCT.

Based on field reconnaissance test, there is no GSM signal in most part of the project area, with the progress of project development and communication development of Southeast Asian countries, communication modes including the public communication, GPRS and program-controlled telephone in the drainage basin will develop also. Therefore, in the long run, it is feasible to consider the ASHDCT of Pak Beng HPP as per satellite communication and public communication.

According to natural geographical conditions in the drainage basin, and referring to practical experience of ASHDCTs constructed in areas (such as Nam Ou River) with similar conditions and development trend of modern communication and network techniques, the hybrid networking mode including Beidou satellite communication and GSM short message shall be adopted for the ASHDCT of Pak Beng HPP.

According to field channel testing condition, if there is GSM signal, GSM shall be taken as the major communication channel for telemetering hydrological (gauge) stations and telemetering precipitation stations, and Beidou satellite as backup channel; if there is no GSM signal or the signal strength is not enough, the Beidou satellite shall be taken as the major communication channel for telemetering hydrological (gauge) stations and telemetering precipitation stations, and GSM as backup communication channel, replacing the major communication channel till the signal strength meets standards.

8.2 WORK SYSTEM

In the automatic hydrological telemeter system, there are 3 common work systems for data transmission, i.e., the self-reporting type, query-reply type and hybrid type.

8.2.1 Self-reporting Type

Self-reporting type can be divided into random self-reporting and regular self-reporting. In the self-reporting system, the telemeter station transmits automatically real-time hydrological/rainfall data to the central station according to the prescribed time or a prescribed change of parameters measured. The advantage is: real-time performance is strong, and data transmitted by the telemeter station is changing continuously; equipment is working in power down state, with low power consumption; the system has a simple structure, convenient for networking; and the communication is in a single direction, with simple equipment, low cost and convenient maintenance. The disadvantage is: the central station cannot inquiry data of the telemeter station and working state at all times.

8.2.2 Query-reply Type
The telemeter station responds querying of the central station, and then transmits acquired data to the central station. The advantage is: the central station can inquiry data of the telemeter station randomly or regularly; it can change the working state of the telemeter station as needed, with good control performance. The disadvantage is: equipment of the telemeter station are in on-duty state with high power consumption; the communication is bidirectional, with complex equipment; the real-time performance is lower than that of the self-reporting.

8.2.3 Hybrid Type

This type has both advantages of the self-reporting type and query-reply type, and real-time and control performances are better, which is the development trend of working way of ASHDCT. However, Beidou satellite and maritime satellite cannot achieve complete hybrid-type working system; when great flood comes, and staff of hydropower station want to understand real-time hydrological/rainfall changes of each telemeter station, the central station will modify immediately the time interval of timed self-reporting of satellite terminal, to shorten the time interval of timed self-reporting of telemeter stations, namely, equivalent to real-time query of the central station.

The ASHDCT is to provide support service for operation dispatching and flood control of hydropower station, which must ensure the real-time performance and reliability of data transmission, so the hybrid-type working system shall be adopted as the working system of the system. However, adopted the hybrid-type working system, the satellite terminal will be in on-standby state at any time, with high power consumption, have high requirements on power supply system of the telemeter station, and be difficult to assure normal work of telemeter station equipment under continuous overcast and rainy weather condition; adopted self-reporting working system, the system has the timed self-reporting and event self-reporting (increasing reporting when the parameter change reaches the set value) function of in-situ and remote programming and controlling function, when great flood comes, each telemeter station will increase to transmit data to the central station if the rainfall or water level changes to the set value, which has already met forecasting need fundamentally.

Meanwhile, real-time discharge data of Yunjinghong HS and Chiang Saen HS (equivalent to Ban Tung Station in this system) will be published on the MRC Secretariat website, which can be available for free inquiry; and Chiang Saen HS can control fundamentally 70% inflow of Pak Beng and the forecast period is very long. Based on consideration of these factors, the self-reporting working system is adopted for the ASHDCT of Pak Beng HPP, however, telemeter stations are allowed to modify parameter command at the time point of telemeter station timed starting to respond the central station.
9 POWER SUPPLY AND LIGHTNING PROTECTION

9.1 DESIGN OF SYSTEM POWER SUPPLY

9.1.1 Design of Power Supply for Telemeter Station

The way of floating charge of solar panel to the storage battery is adopted as the power supply of the telemeter station. 12V is generally used as DC power supply voltage, with voltage change within ±10% range, to ensure normal operation of electric equipment.

In order to ensure that the system is under the operation mode of "supervised and unattended operation", and telemeter station equipment can work reliably and normally in harsh conditions of lightning, storms and power failure, DC power supply of floating charge of solar panel to the storage battery shall be adopted as the power supply of the telemeter station, with clamped control of charging voltage. The advantage of DC power supply of floating charge of solar panel to the storage battery is to be capable of preventing inductive lightning strike to prevent power lines from being damaged in heavy weather to cause power failure of the grid, impacting normal work of telemeter station equipment.

The power of solar panel, capacity of battery and charging controller shall be selected subject to calculation according to following factors:

- Equipment power consumption, including on-duty power consumption, working power consumption and power consumption of communication devices to transmit data.
- Ensure that equipment can maintain normal operation in the condition 40-day continuous overcast and rainy weather.
- It can charge the battery sufficient within 10 days after 40-day continuous overcast and rainy weather.
- Local sunshine index.
- Clamp voltage threshold of the charging controller shall ensure to charge the battery sufficient but avoid overcharge to damage telemeter terminal.

Beidou satellite or GSM (GPRS) communication mode shall be adopted as data transmission communication of the telemeter station, and the communication device will be in power down state after completing data transmission, however, when flood comes, the performance of solar battery components needs to improve greatly due to the communication terminal is on standby at any time, and the specific configuration shall be determined subject to calculating according to actual condition.

9.1.2 Power Supply Design for Central Station

The temporary central station of ASHDCT of Pak Beng HPP in construction period is proposed preliminarily at the Employer's camp, and hydrological information forecasting center station in operation period is arranged in the Construction Management Department of Pak Beng HPP, both have reliable AC power supply; power supply configuration includes AC uninterruptible power supply and DC uninterruptible power supply according to voltage grade and power consumption of electric equipment.
(1) DC uninterruptible power supply

Battery power supply shall be adopted for communication device of the central station, with power supply of AC charger float-charging.

(2) AC uninterruptible power supply

In order to ensure the data receiving system of central station to run continuously for corresponding time in case of power failure, UPS power supply shall be adopted for major equipment of data receiving system (including data receiving computer, communication device, switch and database server), configuring battery box, and UPS power supply time shall not be less than 4h.

9.2 DESIGN OF SYSTEM LIGHTNING PROTECTION

Lightning disaster is one of the most serious natural disasters, and accidents of fire, explosion, information system breakdown caused by lightning occur frequently. The satellite, communication, navigation, computer network system, communication and command system and outdoor antenna equipment system are even severely afflicted area of lightning. In a sense, the more developed technology, the more hazardous lightning stroke to human being.

There are mainly three aspects of the hazard of lightning stroke:

The first is the direct lightning stroke. It refers to strong discharge of a thundercloud to a point of earth. It can strike equipment directly, such as lightning strikes overhead lines, including power lines and telephone lines, etc. The thunder and lightning flow accesses equipment along wires, causing damage.

The second is inductive thunder. It can be divided into electrostatic induction and electromagnetic induction. When the charged thundercloud (negatively charged generally) appears over the wire, a great number of opposite charges are bound up on the wire due to electrostatic induction action. Once the thundercloud discharges to a object, the negative charge in the thundercloud will disappear instantly, at this time, large amounts of positive charges on the wire still exist, and access the ground along the wire through equipment in the form of lightning wave into, causing damage to equipment. When lightning current flows into the earth along the conductor, strong alternating electromagnetic field will appear in the vicinity of the conductor due to high frequency and high strength, if there are equipment in this field, very high voltage will be induced, causing damage. Sensitive electronic equipment shall be paid particular attention to.

The third is lightning wave intrusion. Lightning wave intrusion refers to the lightning action on overhead lines or metal pipeline, lightning waves can intrude along the pipeline, thereby endangering the safety of equipment and personnel, they can cause damage to equipment and personnel in an area, causing serious hazard.

In the following, system telemeter station shall be designed to carry out lightning protection and take corresponding measures against three aspects endangered by the lightning.
9.2.1 Lightning Protection Measures for Telemeter Stations

All telemeter stations constructed newly in the system shall be implemented in accordance with three dimensional protection, needing to consider the protection measures from aspects of the direct lightning stroke, lightning induction and lightning wave intrusion, detailed lightning protection measures for telemeter stations are as follows:

(1) Lightning protection grounding system

Measures of lightning rod, down conductor and lightning ground connector shall be taken mainly to form the lightning grounding system, detailed measures are:

Flat steel and angle steel are used to lay annular grounding grid surrounding outside of integration instrument room constructed newly (or private houses rented); lightning rods are mounted on the roof, and lightning rod height shall make the protection range be 45° angle of elevation with the lightning rod; all the instrument room, instrument box, antenna, solar panels are within the range of lightning protection. The lightning rod, down conductor and grounding grid shall be interconnected firmly, to form the lightning protection grounding system; in site construction, the precision grounding resistance meter shall be used to measure grounding resistance, and long-acting resistance reduction agent shall be applied around the grounding grid to make the resistance be less than 10Ω when the resistance does not reach below 10Ω.

(2) Lightning protection facilities

If equipment are placed in existing station rooms or other buildings of the telemeter station, the configuration of lightning protection facilities including lightning rod and down conductor shall make full use of the foundation of original construction, accessing the lightning rod, down conductor and grounding lead wire to the grounding grid separately, and this grounding grid shall be about 3 meters from lightning protection grounding grid of equipment, and interconnected firmly to foundation grounding grid of buildings, forming the lightning protection grounding system.

(3) Use DC power supply with solar battery floating charge

In order to prevent the lightning from intruding directly from the power supply, the DC power supply with solar battery floating charge shall be used for the telemeter station.

(4) Signal cable protection

Conductor lightning attraction shall be paid attention to for signal cables accessing the telemeter station, and the signal cable shall be buried into the protective tube, and high altitude suspension should be avoided.

(5) The cylinder-type telemeter station itself has a good anti inductive thunder performance due to its double-cylinder metal structure, therefore, lightning protection antenna may not be erected, but the large cylinder must be buried to sufficient depth (pit depth shall not be less than 60 cm), and any cavity shall be avoided as being consolidated with concrete.
It is recommended to use cylinder installation method for telemeter precipitation station for this system. When using commission method to construct the station or site, the lightning grounding must be reliable, to ensure the safety of neighboring residents.

9.2.2 Lightning Protection for Central Station

Lightning protection measures of the central station of are mainly lightning protection for the satellite antenna and alternating current.

The lightning rod shall be erected with the roof of buildings of the central station, so that the antenna is within the lightning rod protection angle (360°). A closed ring conductor has been laid on the building roof of the central station, laying the grounding grid, with a grounding resistance less than 1Ω. Circular grounding bus shall be provided in machine room, the working grounding and protection grounding of all equipment shall be connected reliably to the bus with the shortest distance. Four connection lines arranged symmetrically shall be used to connect the grounding grid, and circular grounding bus reliably.

Details are as follows:

- The lightning rod shall be mounted on the tower top where to erect the antenna, and the tower body and lightning rod shall be reliably grounded, which can be connected to the building grounding well;
- The coaxial lightning arrester shall be mounted between the communication antenna and radio station;
- The AC power supply should be induced through the isolation of 1:1 insulation transformer, with the isolation voltage greater than 8,000V, and the isolation transformer core shall be connected to the building protection grounding;
- Three-phase-five-wire system shall be adopted for AC power supply, one working grounding wire and one protective grounding wire, and the two grounding wires shall be used separately;
- The central station room shall have a metal shielding net, laying circular grounding bus;
- Equipment protective grounding, working grounding and building lightning grounding (including all kinds of grounding terminals such as the circular connection busbar, USP power supply and coaxial lightning arrester) shall be combined into one point to ground, with a grounding resistance less than 1Ω;
- In order to eliminate the overvoltage accessing indoor equipment through the pipeline running into machine room of the central station, the metal pipeline shall be grounded before entering the room;

In construction period, equipment of hydrological information central station shall be placed in the camp of the Employer, required to construct lightning protection facilities; and in...
operation period, equipment of hydrological information central station shall be placed in the powerhouse of the hydropower station, so lightning protection facilities of the powerhouse can be borrowed directly, not necessary to construct separately lightning protection facilities for the hydrological information central station.
10 EQUIPMENT CONFIGURATION AND TECHNICAL REQUIREMENTS

Equipment includes ones of telemeter stations and central station. In this stage, only the function, technical requirements, types and specifications of major equipment are initially determined to meet the need of preparing estimates.

10.1 EQUIPMENT CONFIGURATION OF TELEMETER STATIONS

10.1.1 Function of Telemeter Stations

According to the principle of system construction, the water level sensor with a resolution 1.0cm shall be adopted for water level collection of telemeter stations, and 1.0 mm rain gauge for rainfall collection, and telemetering terminal equipment of data collection processor and Beidou satellite communication terminal equipment shall be configured, to achieve automatic collection of water level and rainfall, solid state storage, automatic switching of communication channel, automatic transmitting to the central station, and the discharge and water level value observed manually shall be transmitted to the central station with the method of artificial setting and transmission with the number-setting keyboard. The telemeter station has following functions:

- Water level and rainfall automatic collection: when water level and rainfall value change up/down or reach a time interval set, it can conduct automatic collection and storage of water level and rainfall data, and transmit according to the real-time level values and cumulative rainfall values.
- Timing self-reporting: when there is no change of hydrological parameters, it can transmit current water level and rainfall data to the central station as per a timing time interval preset, including parameters of the No. of telemeter station, time, battery voltage simultaneously, etc.
- Reporting additionally as exceeding values: in the specified time interval, it will report additionally automatically when water level amplitude and rainfall exceed values set. Time interval and values set shall be programmable.
- On-set solid state storage: the water level and rainfall acquired can be stored on-site. It can respond to the command of the central station, and transmit data stored on-site by batch. At the same time, it also can allow on-site personnel to browse and download data.
- Query-reply inquiry: it can respond inquiry command of the central station, but with a certain delay.
- On-site or remote programming: it can conduct various parameters setting or reading operation on set or remotely.
- Automatic time calibration: it can conduct automatic time calibration through the satellite or receiving command of the center station.
• Self-maintenance functions: it shall have self-maintenance functions including regular condition report, low voltage alarm, power-down protection and automatic reset.

• Working environment: it shall be able to work normally under severe conditions of lightning, rainstorm and power failure.

10.1.2 Technical Requirements for Telemeter Station Equipment

On sensors: accuracy requirements on collection of rainfall and water level are shown in Table 6.2-1.

It can ensure for equipment to work under the environment of temperature -10°C~50°C and the humidity less than 95% (40°C).

The MTBF of rain sensor equipment shall be no less than 40,000h, and MTBF of other types of water gauge shall be no less than 8,000h.

Other requirements:

• Anti-clogging: rainfall sensor shall have measures of anti-clogging, insect resistant and dustproof. It can work normally at least 30d free of clogging under the condition of no manual maintenance.

• Lightning protection and anti-interference: rainfall, water level sensors and transmission lines for output signals shall have lightning protection and anti-interference measures.

• Water level variability: the water level variability that water level sensors can adapt shall be no less than 40cm/min for general conditions and no less than 100cm/min for conditions with special requirements.

• Wave suppression: the output of water level sensor shall be stable, and wave suppression measures shall be taken when necessary.

• The case shall have the structure or measures of moisture-proof, dust-proof, salt spray proofing and rainproof.

• For power supply adaptation, DC power supply shall be give priority to, being able to supply power to sensors alone, or supply power uniformly with the telemeter terminal equipment. When using DC power supply, the voltage value is allowed -15% ~+20% of rated voltage; when using AC power supply, the voltage value is allowed ±20% of rated voltage.

• The telemeter station with average monthly normal operation rate of system data collection reaching average over 95% (the important control station must be included) can transmit data accurately to the central station. Bit error rate shall not be greater than 1 x 10^{-4}.

• 8) MTBF of communication terminal equipment shall not be less than 25,000h.
Main technical indicators of each sensor, solid-state memory and communication terminal equipment shall be in line with corresponding standards and procedures of the nation, industries, associations and organizations.

Work environment conditions shall be assessed by classification as per GB/T9359-2000 based on the actual use environments.

10.1.3 Structure of the Telemetering Station

In order to ensure a reliable system as well as its effective operation and full play to its role, the system must be equipped with the new automatic forecasting technology, modern communication technology and the remote programming control technology. Therefore, the structure design with the integration of measuring, forecasting and controlling is adopted in each Telemetering Station. The structure is composed of five parts, i.e. the sensor, telemetry terminal, communication equipment, manual data inputting device and power system, which is as shown in Fig. 10.1.

![Fig. 10.1 Structure Diagram of the Equipment of Telemetering Station](image)

10.1.4 Equipment Configuration of Telemeter Stations

Principle for equipment configuration: The primary principle for equipment selection is to meet the technical requirements of the system for equipment. The second principle is to give consideration to the simple and convenient installation, economic applicability and easy maintenance.

Consider the equipment configuration of Telemetering Station under the principles of water
level amplitude, measurement accuracy and economic applicability.

Bubble type water gage is a water level sensor with advanced performance, good applicability and high reliability. It is equipped with a high-precision pressure sensor, and is suitable for the collection and transmission of water level and temperature data. The water gauge needs no water level well and has a convenient installation, so it is widely applied as the water level sensor and temperature sensor under various terrains and weather conditions. It has such characteristics as low-power consumption, higher precision and reliability, full temperature compensation, anti-interference design, easy installation and maintenance. As each hydrological and gauging station as the collection station for the important permanent data of operation period is farther from the key station and leads to inconvenient management and maintenance, in order to ensure accurate and reliable data as well as convenient maintenance and management, bubble type water gage is recommended for each gauging station.

(1) Telemetering hydrological station

The system consists of eight telemetering hydrological stations, i.e. Guanlei, Ban Xieng Kok, Ban Tung, Hougy Xai, Mae Nam Yam River, Theong, Namtha River and Pak Beng Telemetering Hydrological Stations. Of which, Guanlei Station is in China, so the preliminary consideration is that Guanlei HS is entrusted by Guanlei Station to report information, without the consideration of water level monitoring equipment, but the station must be equipped with a set of Beidou Satellite/GPRS (GSM) communication terminal and a set of data extraction and transmission software. The rest stations are all in Laos and gauge the rainfall concurrently, so they are configured by the tour-gauging hydrological station and the specific configuration is shown in Table 10.1-1.

<table>
<thead>
<tr>
<th>Item</th>
<th>Number</th>
<th>Unit</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bubble type water gauge</td>
<td>1</td>
<td>Set</td>
<td></td>
</tr>
<tr>
<td>Manual water gauge</td>
<td>1</td>
<td>Set</td>
<td></td>
</tr>
<tr>
<td>Rain gauge</td>
<td>1</td>
<td>Piece</td>
<td>If the site of each hydrological station is nearer to the residence, the instrument container may be adopted and under the care of nearby commissioned resident, otherwise the instrument shelter shall be adopted.</td>
</tr>
<tr>
<td>Data collection processor</td>
<td>1</td>
<td>Piece</td>
<td></td>
</tr>
<tr>
<td>Beidou Satellite terminal and antenna</td>
<td>1</td>
<td>Set</td>
<td></td>
</tr>
<tr>
<td>GPRS (GSM) terminal</td>
<td>1</td>
<td>Piece</td>
<td></td>
</tr>
<tr>
<td>Solar panel and support</td>
<td>1</td>
<td>Set</td>
<td></td>
</tr>
<tr>
<td>Accumulator battery</td>
<td>1</td>
<td>Pcs.</td>
<td></td>
</tr>
<tr>
<td>Integrated instrument container (instrument shelter)</td>
<td>1</td>
<td>Piece</td>
<td></td>
</tr>
</tbody>
</table>

(2) Telemetering gauging station
Gauging station in the system consists of KengPhaDai, upstream and downstream cofferdams, gauging station in front of the dam and the stations in the entrance and exit to approach channel, of which, gauging station in front of the dam and the stations in the entrance and exit to approach channel are newly-built stations in operation period. Among the above stations, KengPhaDai, upstream cofferdam and gauging station in front of the dam are in charge of rainfall monitoring in addition to water level monitoring, while the rest gauging stations only monitor the water level. Specific major equipment configuration of each gauging station is shown in Table 10.1-2.

<table>
<thead>
<tr>
<th>Item</th>
<th>Number</th>
<th>Unit</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bubble type water gauge</td>
<td>1</td>
<td>Set</td>
<td></td>
</tr>
<tr>
<td>Manual water gauge</td>
<td>1</td>
<td>Set</td>
<td></td>
</tr>
<tr>
<td>Rain gauge</td>
<td>1</td>
<td>Piece</td>
<td>Rain gauge is only configured for KengPhaDai Station, upstream cofferdam station and gauging station in front of the dam, while the rest stations are not equipped with the rain gauge</td>
</tr>
<tr>
<td>Data collection processor</td>
<td>1</td>
<td>Piece</td>
<td></td>
</tr>
<tr>
<td>Beidou Satellite terminal and antenna</td>
<td>1</td>
<td>Set</td>
<td></td>
</tr>
<tr>
<td>GPRS (GSM) terminal</td>
<td>1</td>
<td>Piece</td>
<td></td>
</tr>
<tr>
<td>Solar panel and support</td>
<td>1</td>
<td>Set</td>
<td></td>
</tr>
<tr>
<td>Accumulator battery</td>
<td>1</td>
<td>Pcs.</td>
<td></td>
</tr>
<tr>
<td>Integrated instrument container (instrument shelter)</td>
<td>1</td>
<td>Piece</td>
<td></td>
</tr>
</tbody>
</table>

The gauge station is required for KengPhaDai and the upstream and downstream cofferdam. Gauges station in upper dam and the stations in the entrance and exit to approach channel shall be painted with marking pigment or inlaid with water gauge porcelains during the construction of the dam so as to reduce the workload of setting up the water gauge. Stations in upper dam, the entrance and exit to approach channel are in the junction area, so they may make use of the installation method of nearby station building or the integrated instrument container for reference.

(3) Telemetering precipitation station

Considering better effect of lightning protection, the installation method of metal cylinder is recommended for the telemetering precipitation station in the system. Major equipment configuration is shown in Table 10.1-3:
Table 10.1-3  Major Equipment Configuration of Telemetering Precipitation Station

<table>
<thead>
<tr>
<th>Item</th>
<th>Number</th>
<th>Unit</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain gauge</td>
<td>1</td>
<td>Unit</td>
<td></td>
</tr>
<tr>
<td>Data collection processor</td>
<td>1</td>
<td>Piece</td>
<td></td>
</tr>
<tr>
<td>Beidou Satellite terminal and antenna</td>
<td>1</td>
<td>Set</td>
<td></td>
</tr>
<tr>
<td>GPRS (GSM) terminal</td>
<td>1</td>
<td>Piece</td>
<td></td>
</tr>
<tr>
<td>Solar panel and support</td>
<td>1</td>
<td>Set</td>
<td></td>
</tr>
<tr>
<td>Accumulator battery</td>
<td>1</td>
<td>Pcs.</td>
<td></td>
</tr>
<tr>
<td>Faraday cylinder</td>
<td>1</td>
<td>Pcs.</td>
<td></td>
</tr>
</tbody>
</table>

(4) Measurement range and precision of the equipment of Telemetering Station

- **Measurement range**

  The measurement range of water gauge is determined by the location of hydrological (gauging) station.

  —The measurement range in telemetering hydrological station is the minimum water level within the period from 100-year return period flood level to the operation of sensor.

  —The measurement range in telemetering gauging station is the minimum water level within the period from 50-year return period flood level to the operation of sensor.

  Certain transfinite forecasting measures shall be taken for the measurement range.

- **Precision**

  The precision shall meet the provisions in Table 6.2-1.

10.2  SYSTEM EQUIPMENT CONFIGURATION OF THE CENTRAL STATION

The Central Station of hydrological information forecast provides software and hardware platforms for hydrological information forecast and information service. It mainly consists of hydrological information receiving and processing system, database, and computer network system. Because of the longer construction period of Pak Beng HPP and poor living conditions in the hydropower station in early stage, two stages of construction are temporarily decided for the Central Station of hydrological information forecast system of Pak Beng HPP, i.e. the two-stage construction of temporary central station for construction period and permanent central station in operation period. Preliminary consideration is to establish temporary Central Station for construction period in the Employers' campsite and the permanent central station for operation period in the surveillance & control center of power
station or the operation management department of power station.

10.2.1 Structure and Function of the Central Station

The Central Station is the "central nervous system" of the system and is responsible for information receiving and processing, database management, and providing software and hardware platforms for hydrological information forecast and information service. It consists of mainly of three parts: hydrological information receiving and processing system, database, and computer network.

The main functions are as follows:

- Data receiving and processing: It can real-timely receive the information of rainfall regime and hydrological information from Telemetering Station. It can make inspection, error correction, interpolation, classification and formatting of data, fill time marks, automatically inspect the data frame format, make a reasonable discrimination, create calculating table and database and achieve automatic storage. It can receive and handle the hydrological information telegram and the data and materials transmitted by other forecasting systems, can input the data into the database of the forecasting system through message translation and data format conversion;

- Response and inquiry: It can inquire the water level, precipitation and working state of subordinate stations at a fixed interval or manually. It is able to transmit water level and rainfall records by batch at specified periods. It can specify the communication mode, and correct the clock and startup & shutdown of Telemetering Station;

- Database management: It includes the formation, retrieval and inquiry, etc., of original, historical, prediction or achievement database;

- Data output: It can output the histogram of rainfall, water level, runoff hydrograph and isohyet map, etc. through such equipment as screen, printer and graph plotter, etc.;

- Flood forecasting: It can automatically complete the forecasting functions of different solutions, control the operation of the forecasting software through human-machine dialogue, and forecast when the telemetering information misses. It includes flood forecast parameter initialization, parameter setting/modify, timing forecast, off-line estimating forecast, result storage, printing and output;

- Networking communication: It can achieve access local area network for data sharing and reserve wide area network interface;

- Status alarming: It can alarm when the rainfall or water level or flow rate, etc. exceeds a certain specified value; can alarm when power supply of the equipment is deficient and the voltage of the devices drops, especially when the power supply
The capability of Telemetering Station falls below the threshold value that has been set. In order to attract timely attention of the staff, audible and visual alarm ways can be used in addition to the screen display alarm;

- It has the data maintenance function of security and confidentiality, providing data backup to ensure data security.

10.2.2 Technical requirements on hardware equipment of the Central Station

The unimpeded rate of data transmission of the system shall be larger than 99% and the bit error rate shall be less than $1 \times 10^{-4}$.

It can ensure for equipment to work under the environment of temperature $5^\circ C$~ $40^\circ C$ and the humidity less than $90\% (40^\circ C)$.

Comprehensive MTBF of the equipment shall be no less than 6,300h.

The key technical indexes of equipment shall conform to national and industrial standards and procedures as well as those of associations and organizations.

10.2.3 Hydrologic Data RecEiving and Processing System

(1) System structure

Hydrologic information receiving and processing system is mainly composed of satellite terminal equipment, data processing computer and data receiving and processing software.

The hydrologic information of each hydrologic Telemetering Station is firstly transmitted to the central station through GPRS (GSM)) and Beidou Satellite communication channel, then is input into the information receiving and processing computer, thus to complete the receiving and processing of real-time, timing and batch data of hydrologic and rainfall regime through data receiving software and store the result into the real-time database. The data receiving and processing computer connected with the computer local area network of the central station can synchronize data after storage into the application data server for back-up. It can achieve the back-up of data and information sharing.

(2) Main Functions and Requirements

a. It can real-timely receive the real-time data from each Telemetering Station within the system, including water level, rainfall and working condition, etc.;

b. Make reasonable analysis and debugging on original data and store the data into archives database by classification;

c. Make manual correction or interpolation on the defect;

d. Monitor the working conditions of Telemetering Station, including clock calibration and other operation parameters and voltage alarm, etc.;

e. Has the function of inquiry, maintenance of real-time information and data backup.
10.2.4 Database

Database management system, the core department of automatic telemetering system for hydrological information, must best satisfy the requirements for the functions and performances of the system.

Centralized management and the database structure with hierarchical & distributed application are adopted for the data architecture on the whole. A primary & standby redundant database management system is established in the center and in charge of real-time data collection and historical data management. The database management system in the central station shall be applied with the relational database management system that has advanced technology, conform to the international standard, has powerful functions and easy development and management.

10.2.5 Computer local area network

According to the current network situation and network application requirements as well as the development trend of network in the future, the design on the computer networks in the Central Station shall meet the following requirements:

（1）Practicability of network

Considering the demand of various business application for computer networks, the requirements for the speed and capacity of computer network shall be meet for the convenience of the information receiving and professing, database creation and hydrological information service, etc.

（2）Reliability of network

Consideration shall be taken based on the network topology and the reliability of network equipment to meet the requirement for continuous 24-hour operation of network system.

According to the aforesaid development principle, dual-redundancy configuration shall be adopted for the database server.

The software of the system shall provide reliable backups and have backup management strategy to make sure rapid restoration of the system in the case of disaster.

（3）Safety of the network

Firstly, it shall prevent the access of external illegal users, secondly, it shall prevent the unauthorized access of internal legal users.

（4）Expandability of network

Two aspects shall be considered: The first one is that the network scale can be expanded, but great change shall not be made in either network structure or main
equipment during the expansion of network scale. Therefore, allowance shall be reserved for the expansion of network equipment and module, and the main network equipment selected shall carry expandable modules. Network equipment can increase the remote and local port numbers by easily adding modules thus to provide network interface for the scale enlargement of future system and the access to new system. The second aspect is that the topological structure of the network can be changed flexibly. The international popular network technology and platform are adopted to adapt to the development of the system and achieve good vertical and horizontal compatibility of the system.

10.2.5.1 Main functions

- It can satisfy the requirements of automatic collecting, processing and controlling of real-time hydrologic data information from Telemetering Station, can provide a rapid, stable and safe software and hardware platform for the receiving and processing of hydrologic information from the system as well as information exchange and service.
- It can establish the systems of "real-time database" and "historical database", etc. and provide the functions of inquiry, maintenance and management.
- It can provide the WEB-based information inquiry and service for the use of information within the Internet.

(1) Network architecture

The switched local area network of mainstream operating system is adopted to form the open system with function distribution. The computer uses the standard local area network (LAN) for connection, and distributes the server and working station according to functional module.

The data collection computer adopts the point-to-point way to realize synchronization of data after being acquired or processed to the data application server. The system can adopt the operation mode of Client/Server (C/S) or Brower/Server (B/S) or the combination of them. The user working station should adopt the operation mode of Brower/Server (B/S). The Web server should adopt the multi-layer structure.

The external interconnection of computer network of the Central Station adopts TCP/IP protocol, the local area network shall support protocols such as TCP/IP, IPX/SPX and NetBEUI, etc. The information query and release adopts the operation mode of Internet/Intranet or operation mode of Client/Server (C/S) or Brower/Server (B/S).

(2) Network topology

The open bus structure network system is adopted, the work form of computer adopts the Client/Server type structure, which is flexible and changeable, with good extensiveness, and can be configured flexibly according to the users' needs.
The database server and disk array are configured in the Central Station, which are responsible for related applications of all hydrological informations and storing and processing of data, set application server (mainly operate the middleware of data interface so as to realize efficient access to database of all applications and achieve dual network redundancy and switch, which thus improves the reliability of the system. In addition, the key processes operating continuously on the application server such as real-time data processing, conventional data processing, automatic calculation of water affairs, alarm analysis service), communication server, hydrological information analysis working station and other network system form the hydrological information central system.

Set WEB server through the exchange data information between communication server and Telemetering Station, and realize data communication and WEB browsing with hydrology department, meteorological department and other related department through firewall.

The data communication with hydrology department, flood control and drought resistance department and other related department is realized through Internet, and the security isolation system shall be set for the connection.

The hydrological information system belongs to Area II in the Internet, and the security isolation system shall be set for its connection with mobile communication and satellite communication suppliers, hydrology department, meteorological department, etc. so as to ensure the safe operation of hydrological information telemetry system.

The network topology of Pak Beng HPP is shown in Fig. 10.2-1.
Fig. 10.2-1  Network topology of center station of hydrological information telemetry system of Pak Beng HPP
(3) Network and data security measures

The computer network system of the Central Station is an open network structure system with TCP/IP as the core, and the features of open network makes it be exposed to intrusion and attack from all respects at any time, therefore, it is necessary to build a multi-layer security framework to ensure the security of system network.

a. Build relatively independent network system

The data application server and computer used for forecasting operates independently, the individual computer (data collection computer and network server) is adopted for connection.

b. Secondly, prevent the exceed authority access of internal legal users.

Set the function of user privilege management in the operation management of system.

c. Data copy and recovery safety measures

Configure necessary copies for key network resource (key equipment and data).

It is necessary to carry out the copy work of hard and soft copy of fixed quantity and time of real-time database formed from data of real-time receiving data, hydrological information database, various service targets database formed by organization and development, etc. Meanwhile, it is also necessary to carry out the copy work of the network structure diagrams, network physical and logical connection diagram, detail file of network function, safety technical documentation, installation process of software and server and configuration data of network devices, etc.

d. Other measures

All computers in the Center Station are installed with XP Home, which are upgraded timely to plug up the leak of the system to prevent malicious invasion and damage by making use of the leak of the system.

Install the genuine antivirus and firewall software to try to prevent the computers in center station contracting the virus.

Establish perfect network and computer management regulations, and the working personnel shall not use the computers in the system to do anything that has nothing to do with work.

10.2.6 Device configuration of the central station

(1) Hardware device configuration

During construction period, there are 7 telemetering hydrological stations in total, 3 telemetering gauging stations in total and 15 telemetering precipitation stations in total, the configuration of computer network facilities must meet the requirements for computer network speed and capacity such as information receiving processing, database construction and hydrological information service, etc., and margin shall be reserved. The
equipment configuration of temporary center station of Pak Beng HPP during construction period is shown in Table 10.2.

Table 10.2  Table of main equipment configuration of temporary Central Station of hydrological information automatic telemetry system of Pak Beng HPP during construction period

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of equipment</th>
<th>Unit</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(I)</td>
<td>Computer and network communication equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Database server</td>
<td>Unit</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Disk array</td>
<td>Unit</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Web server</td>
<td>Unit</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Application server</td>
<td>Unit</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Desktop computer</td>
<td>Unit</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Portable computer</td>
<td>Unit</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Exchanger</td>
<td>Unit</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>UPS power supply</td>
<td>Unit</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Firewall</td>
<td>Set</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Router</td>
<td>Unit</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Cabinet of the server and KVM kit</td>
<td>Set</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Satellite terminal and GSM communications equipment</td>
<td>Set</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Isolation equipment</td>
<td>Set</td>
<td>1</td>
</tr>
<tr>
<td>(II)</td>
<td>Other equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Computer desk and chair</td>
<td>Set</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>Satellite phone</td>
<td>Unit</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>AIO (printer, fax machine and copy machine)</td>
<td>Unit</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Multi-function testing instrument and maintenance tool</td>
<td>Set</td>
<td>1</td>
</tr>
<tr>
<td>(III)</td>
<td>Spare parts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Tipping-bucket rain gauge</td>
<td>Piece</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Data collection processor</td>
<td>Unit</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Satellite terminal antenna and GSM communications equipment</td>
<td>Set</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Solar energy panels</td>
<td>Block</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Charge controller</td>
<td>Set</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Accumulator battery</td>
<td>Pcs.</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Bubble type water gauge</td>
<td>Pcs.</td>
<td>2</td>
</tr>
</tbody>
</table>

After entering the operation period, the configuration of main equipment in hydrological information information center basically remains unchanged, the
equipment can be added based on needs to meet the need of communication of monitoring system of hydropower station and communication of power dispatching so as to realize the upgrading of hydropower dispatching automation.

(2) Workflow and software configuration of the Center Station

See Fig.10.2-2 for workflow diagram of center station.

![Workflow diagram of center station](image)

**Fig. 10.2-2  Workflow diagram of center station**

The main workflow of hydrology automatic measurement and forecasting system is: receive the telemetering data of the system and hydrological information telegram delivered in the way of on-line and hydrographic data of external system, carry out the processing and storing into database of data received, compile the hydrographic chart, and implement the optimization of dispatching operation and model parameter, and deliver the data to the hydrological information information users.

The software of the system can be basically divided into three categories of system software, support platform software and application software according to function.
a. System software

The system software shall adopt those complying with international standards and shall be the latest version, which is mainly used to support computer operation and maintenance of the system, development of user program, drive and management of peripherals, including operating system, check and diagnosis program, high-level language compile program, etc., it is the foundation for the effective work of hydrological information automatic telemetry system.

The operating system shall support the real-time, multi-task and multi-user operating environment, with functions of memory dynamic allocation, outer memory management and on-line debugging, possessing the computer system performance monitoring and diagnosis program, and supporting the function of network communication; the data application server and network server shall choose the Windows Server; the working station adopts the Windows Professional mainstream operating system.

After the computer is powered up, it can perform self-start and self-guide, and enters the on-line operation status. Some checking programs can be started during on-line operation, which are used to perform diagnosis after occurrence of error, with the functions of on-line and off-line diagnosis of fault location.

b. Support platform software

The support platform software communicates the link between application software and operating system, and is a key composition of hydrological information automatic telemetry system.

The support platform adopts the most advanced software technology to realize the disrelation between hydrological information telemetry software platform and hardware platform, support the integration of third-party application software, and realize the effective interconnection with local area network system.

The support platform provides various almost universal management and presentation tools for application software of the system, including various tool softwares such as graph management, statement management, data communication, system maintenance (including fault monitoring, switch and launching of software, alarming and network management, etc.).

The support platform realizes the database management and realizes the corresponding data access through middleware.

The support platform software system is designed in the way of three-layer structure.

The three-layer structure means to divide the data processing procedure into three parts: The first layer is client-side (user interface), providing friendly visit between user and system; The second layer is application server, specially taking charge of realization of service logic; The third layer is data server, taking charge of the storage, access and
optimization of data information. The three-layer structure adds the application server on the basis of traditional second-layer structure, separately processing the application logic, which thus enables the user interface and application logic to be located in different platforms, and the communication protocol between them will be defined by the system on itself. The application logic is shared by all users with such structure design, which is the biggest difference between two-layer application software and three-layer application software. The advantage of such three-layer data processing is like to add standardized processing factory and transmission route to the two-layer structure, which can realize high-efficient production and deliver the desired product to client-side.

Specifics are as follows:

- The whole system is divided into different logical blocks through three-layer data processing, which greatly reduces the cost of development and maintenance of the application system. The three-layer separates the represent part and service logic part according to the client layer and application server, the communication between client and application server, communication between application server and database, data exchange among heterogeneous platforms, etc. can be realized through middleware or relative program. When the database or service logic of application server changes, the client-side will not change, which thus greatly improves the reusability of system module, shorten the development cycle and reduce the maintenance cost.

- The expansibility of the system is greatly enhanced. The modularization of system enables the system to expand in the vertical and horizontal direction easily, which can not only upgrade the system to be larger and more powerful platform, meanwhile, add proper scale to enhance the network application of the system. Since it overcomes the limit of system homology, so the distributed data processing becomes possible.

The role of three-layer structure in creating enterprise competitive advantage is mainly reflected that its modular design makes the users to achieve system expansion on the basis of existing structures, thus, it improves the speed of enterprise informationization and professional skill. Meanwhile, the appearance of middleware of three-layer structure enables the users to choose suitable products from the market directly to build the system, which greatly reduces the development cycle and development cost. The three-layer data processing structure based on the middlewares shall promote informatization of the enterprise quickly and better and improve the enterprise's competitiveness.

Support platform softwares mainly include the following categories:

- Database and database management system

There are various data in the hydrological information automatic telemetry system, including real time data and delayed data of Telemetering Stations, power station and other data source systems, etc.; historical data preserved for long-term as historical materials; various calculation data and operating status data of system devices; various
application data, service data and generated data.

Database and database management system support to set up the classification database and conduct its efficient management. Various performance indexes of the database can meet the requirements of system function and performance. The database shall have good instantaneous, reliability, expandability and adaptability, data model shall meet the characteristics of hydrological information automatic telemetry system.

To facilitate the expansion of data scale and the updating of forming structure between data, the database administrator shall be compatible to the high-level language writing system applications, application program can visit the database by various ways.

Database management system is constituted by historical database management system and real time database management system. Historical database management system shall adopt the database and management system with the commercial, general and latest version (including cluster and various tools software, necessary data warehouse and data mining tools, etc.), to store the historical data and visit part external system; real time database management system is used to support the rapid access of data and access service of various real time applications and part external system. Both of the two kinds of database shall support the hot standby mechanism for redundant dual-server and ensure the consistency and completeness of the data, on the premise of meeting the performance indexes of water scheduling and based on the commercial database, they shall achieve the unified data management by fully utilizing the computer's strong operational capability, storage capacity and the main memory database under the environment of commercial database.

The hydrological information automatic telemetry system shall provide a drawing management system constituted with drawing management tools and user interface, which shall support basic window operations of zoom, translation, etc.

- Report support system

The report function is one of the basic functions of hydrological information automatic telemetry system, whose basic requirement is to realize dispatch, printing and management of report.

The support platform software can be divided as follows based on function module: database subsystem, data collection and processing subsystem, human machine interface subsystem, short message platform, alarm subsystem, system maintenance management and software of auxiliary function, etc.

(3) Application software

The functions of application software include:

a. Basic application of water

Calculation and management of water mainly refer to:
Basic service function of hydrological information:

Carry out hydrologic calculation for hydrological and rainfall information data according to different algorithms automatically and regularly as well as data classification, reorganization and processing, and store the result in database automatically for use or processing of other application software. Meanwhile, it possesses the functions of report generation (preparing yearly, monthly and quarterly report), various index assessment of hydrologic forecast, traditional calculation and analysis of hydrologic forecast, etc.

Flood control, comprehensive utilization of information and other functions:

It possesses the functions of processing, analyzing and storing of basic data of hydrological information, rainfall and meteorology, etc., as well as providing decision basis for flood control command and management of daily information;

Store various systems and important documents, information and photos, etc. in relation to flood control management, and provide service for flood control;

Carry out analysis, comparison and synthesis for all kinds of real-time data and historical data meeting various applications, and carry out real-time static and dynamic analysis for flood control information. Provide analysis results for the related personnel to make decisions;

Perform real-time dynamic monitoring for flood situation.

b. Hydrological forecasting

The hydrological forecast is the most important part of flood forecast and scheduling software system, and the level of forecast accuracy determines the good or bad usage of application software.

On the basis of flow in entrance of section and measured rainfall, provide the forecast result of rainfall runoff of forecast section and reservoir dam site section, related forecast results of river course, forecast results of real-time correction and comprehensive forecast results (may be subject to manual corrections) by building the runoff-producing and converging model of watershed and runoff evolvement model.

The flood forecast refers to conduct flood forecast for sections by using real-time data in the on-line hydrological information automatic telemetry system, which is required to meet the instantaneity, accuracy and forecast period of forecast.
11 CIVIL ENGINEERING

The construction of road facilities of the Telemetering Station is mainly based on the requirements of the Hydrological Fundamental Facility Construction and Technical Equipment Standard (SL276-2002) and Watercourse Observation Specification. The hydrological station of the system will be built in the way of tour gauging hydrological station, without regard to residential and office space, and the flow gauging personnel shall carry out work in the way of rental residence.

The civil engineering project of the hydrological information telemetry system mainly includes the decoration of instrument chamber, water gauge mounting facilities, bubble type water gage tube well laying, rain gauge mounting facilities, satellite antenna mounting facilities, solar panels mounting facilities, lightning protection facilities and machine room of central station, etc.

11.1 INSTALLATION OF EQUIPMENT

11.1.1 Central Station

Civil engineering of the Central Station includes:

- According to the equipment configuration and operational need of Central Station, the Central Station is equipped with machine room, office and lounge.

- The area of machine room of the Central Station takes 8 - 12 times of that of communications equipment, computer, printer, UPS power source and other support equipment. If the calculate area is less than 20m², it can adopt 20m².

- The machine room and office of the Central Station carry out decoration, the machine room is equipped with conductive floor, configured with air conditioner and fire control facility, etc.

11.1.2 Instrument chamber

In order to reduce the civil engineering investment, the Telemetering Station adopts the civil buildings in principle and means of entrustment for construction. Among which, the rainfall Telemetering Station adopts the way of metal cylinder. It will adopt the way of integrated instrument box for construction if it is guarded over; it shall build the instrument chamber to ensure the safety of instrument if the civil buildings are not available or entrustment is impossible.

11.1.3 Artificial observation water level facility

According to the relevant standards, the facility measuring cross-section needs to be built in the system, including mark, bench mark, protective mark and observation road, etc.

The water gauge adopts the standard structural type, i.e. seamless steel pipe, weld and fix the enamel water gauge buckle in proper position, and the bottom is welded with crossed reinforcing steel bar. Set reasonably based on different height difference when laying along the dock, and carry out concrete pouring and solid filling for seamless steel pipe.
11.1.4 Water gauge mounting facilities

Laying of pressure sensing line of water gauge is necessary for bubble pressure water gauge, and the specific construction scheme is shown as follows:

- The pressure sensing line that water gauge is equipped with is φ10mm polyethylene pipe, to avoid causing damage to the pressure sensing line, 2” galvanized pipe is used as protective casing pipe during laying of pipe, and the laying depth is 0.5m.
- Lay downhill along the slope protection of river bank during laying of pipe so as to avoid counter-slope which will cause dew inside of pressure sensing line, which will affect the measurement accuracy of water gauge.
- During laying of pipe, the pressure sensing line shall be fixed on the rock along the way with pipe clamp. Try to use 135° bend at the pipe joint so as to avoid bending of the pressure sensing line and maintain smooth gas circuit of the pressure sensing line. Reserve a manhole every other 15m.

Water level station in front of the reservoir dam: use two pieces of steel pipes with diameter of 300m on the banks of inlet to replace the concrete gauging well, which are used to place the water level observation facilities. Under the premise of ensuring that the instrument and equipment are not damaged due to natural and human factors, try to make use of the existing road facilities to avoid repeated construction, and the lock chamber of head gate and spillway is also available. Generally, the location of station chooses the edge of wing wall near the power generation irrigating gate, the intake here adopts deep water diversion, with smooth and stable water level, good representativeness of water level, the hydraulic structures have vertical side walls, and the lock chamber can be used as instrument station, so it is not necessary to build another station.

The building area of instrument chamber should not be more than 4m², it is proposed initially to adopt the brick wall enclosure, dimension: 2m×2m×2.5m, it adopts the whole-brick wall, and is covered with cover plate on the top. The rain gauge, satellite antenna, solar charging panel and lightning rod are installed on the roof, while the bubble type water gage, data collection processor and storage battery and other equipment facilities are installed in the chamber. The shutter shall be installed in the instrument chamber, and its brief schematic diagram of installation of is shown in Fig. 11.1-1.

11.1.5 Rain gauge mounting facilities

The rainfall Telemetering Station in the system is proposed to adopt the Faraday cylinder as lightning protection facility, which does not require ground wire and insulation support, with little space occupation, suitable for all weather operation conditions. All selected equipment is adaptable to the severe environment outside, and they shall be designed by continuous operation of unattended operation.

During installation, the anchor frame and concrete base shall be poured together in advance, during pouring, pay attention to let the anchor frame and concrete base remain level and
anchor bolt remain vertical, and pay attention to bind the thread part of anchor bolt with grease in advance.

Considering the difference of field construction conditions, all large metal cylinders adopt the underground installation, whose installation can refer to Fig. 11.1-2.

11.1.6 Mounting stem and mounting base of satellite antenna and lightning rod
The mounting stem of satellite antenna adopts the one welded from φ60mm galvanized pipe with the height of 1.6M and δ8mm steel bottom plate as a whole one, with total length of 1.6m. The directive antenna is equipped with the mounting stem of lightning rod, which adopts the one welded from φ60mm and φ34mm galvanized pip and φ14mm round steel (one end is sharpened to be used as lightning rod) and δ8mm steel bottom plate as a whole, with total length of 3.6m. Among which, the lightning rod and lightning grounding grid shall be connected firmly. In addition, the antenna mounting rack is designed for stations needing to install Beidou Satellite terminal antenna, which can be clamped on the antenna mounting stem.

The schematic diagram of satellite installation of the Central Station is shown in Fig.11.1-3, and the schematic diagram of lightning protection facilities installation is shown in Fig.11.1-4.

11.1.7 Mounting rack and mounting base of solar-cell panel
Due to the geographic location of the system, the angle of altitude of the mounting rack of solar-cell panel is designed as 35° according to the technical requirements of optimal solar radiation energy collection. The mounting rack of solar-cell panel is fixed on the pre-buried anchor bolt in roof deck, facing south. No occlusions shall be in the south of the mounting rack of solar-cell panel.
Fig. 11.1-1  Schematic Diagram of Installation of Instrument Chamber and Pipeline of Water Level Station

Notes

1. In the 11/2" galvanized pipeline, there are signal transmission cables running, so the galvanized pipeline shall be laid down along the slope and the counter-slope phenomena shall be avoided.
2. For the fixed outlet support of a welling well, a q200 and 900 deep pit must be cut in the rock river bed, pouring concrete to make the support be fixed firm in the river bed.
3. Water level probe shall be mounted as vertically as possible to the water surface, and the probe shall be set at 0.5m below corresponding design low water level. The foundation of instrument room shall be set at 0.5m above the design high water level.
4. As mounting, it shall be paid attention to that the orientation of solar panels on the instrument room shall face toward the south, to ensure that solar panels have adequate lighting.
Fig. 11.1-2 Schematic Diagram of Underground Installation of Metal Cylinder of Precipitation Station

Fig. 11.1-3 Schematic Diagram of Satellite Installation of the Central Station
Fig. 11.1-4 Schematic Diagram of Installation of Lightning Protection Facilities
11.2 **Environmental protection and water-soil conservation**

During construction, do well in drainage around the construction site supplemented by proper slope protection projects to guarantee its safety and reduce the destruction of the environment.

After the completion of construction, dismantle timely the construction facilities and temporary houses in the construction site that are no longer be used, and carry out river course dredging, land reclamation, vegetation restoring or reclamation according to the surroundings.

As for the open ground in the project area, the biological measures shall be focused supplemented by necessary blocking and protecting, drainage, land reclamation and other engineering measures in the later stage of the construction, grow lawns, hedges, flowers, fruit trees and some ornamental plants to improve the ecological environment of the project area through design and implementation of point-line-surface small garden.
12 Construction, Acceptance and Operation Management

12.1 Schedule of system construction

The project construction determines the construction organization with corresponding qualifications for design, construction and supervision based on the current management system of the construction project of hydraulic and hydroelectric engineering.

At present, the feasibility study stage of Pak Beng HPP has come to a close, given the tight construction period of the hydropower station, it is proposed to complete the non-nodal region Telemetering Station system once, the temporary Central Station can borrow the Employers' camp site during construction period, and relocate the Central Station of hydrological information automatic telemetry system to management department after the management department of hydropower station is completed.

Complete the construction of center station system and non-nodal region Telemetering Station system of construction period 3 months before the commencement of the nodal region engineering, and complete the construction of water level Telemetering Station of cofferdams at upstream and downstream at the same time, meanwhile, access the stations of all Telemetering Stations to the center station system, and start the hydrological information telemetering forecasting work of construction period. During construction of Telemetering Station, the hydrological (water level) Telemetering Station may be firstly built, followed by rainfall Telemetering Station.

Complete the center station, dam water level station and water level station of approach channel entrance and exit of operation period one month before the hydropower station is put into operation, and access all Telemetering Stations to the center station, which shall be officially put into operation after one month of pilot run, and start the hydrological information telemetering forecasting work of operation period of Pak Beng HPP.

12.2 Assessment and acceptance of system

The acceptance of system assessment shall be performed in strict accordance with the relevant specification, the completion acceptance of project shall be organized by competent organization according to the relevant regulations of the Acceptance Specification for Water Conservancy and Hydropower Construction Engineering (SL223-1999) and Technical Standard for Hydrology Automatic Measurement and Forecasting System (SL61-2003).

After the installing and debugging of the system, the acceptance can only be carried out after going through the pilot run (one flood season).

After the system passes the assessment and acceptance, the construction organization and construction unit shall execute the handover procedure, and the construction unit only completes its work after the completion of handover work.
12.3 Operation management system

12.3.1 Operation management method

The operation and maintenance management of system shall include the following basic work:

- Make rules and regulations and operating procedure for operation management;
- The field Telemetering Station realizes entrust management;
- Attended operation;
- Routine maintenance;
- Regular and irregular inspection;
- Maintenance.

Specifically, the field Telemetering Station can refer to the following ways to carry out maintenance management:

- To save maintenance cost, Guanlei HS and NamTha HS in the system can be handed over respectively to the Hydrology and Water Resources Survey Bureau and primary power station they belong to for maintenance;
- All precipitation stations in the system are built in the village or town with convenient transportation, and the key equipment is built in the house of common people, which are guarded over by the common people at ordinary times, in case of problem to equipment, the professional maintenance staff can also arrive at the station quickly for maintenance treatment.
- Ban Tung HS and Hougy Xai HS in the system can entrust the local common people to guard by referring to the maintenance management modes of all precipitation stations in the system, besides, it is necessary to entrust the common people for artificial water level observation in earlier stage, and the common people shall also deliver the water level that they have observed to the center station to conduct comparison with the water level observed by self-recording water gauge; since the hydrological station in the front of dam and of tail are near the hydropower station, so special personnel can be entrusted for maintenance management and a period of water level observation.
- The tour gauging method shall be adopted for Ban Xieng Kok, Ban Tung, Chiang Rai, Theong, Hougy Xai and Nam Tha and Pak Beng HS in the system to carry out the current surveying work. Among which, Ban Tung HS is located on the opposite of Chiang Saen HS, since Chiang Saen HS has a large amount of data concerning water level and flow, so Ban Tung HS can spare the current surveying if it borrows the relation between water level and flow of Chiang Saen HS, and this design shall temporarily take the measurement.

As for the four groups of water gauges of completed nodal region in the system, the
self-recording water gauge adopt the operation mode of "attended custody, unattended operation", the water level adopts the self-recording way for operation, among which, C and D water gauges adopt the direct water gauge for timed observation, three times per day on average, 8:00, 14:00 and 20:00, respectively; The flow adopts the way of tour gauging, the current surveying work is carried out in dry season and flood season of each year respectively, accompanied with station maintenance.

12.3.2 Personnel Allocation and Technical Training

Full-time management personnel with hydrological forecast experience and knowledge about communication and computer, etc., are required to be responsible for the operation management and maintenance of the system so as to ensure the reliable operation of the system; carry out training concerning installation operation and operation and maintenance of the system for operation management staff.

12.3.3 CONTENT of Operation Management

- Make rules and regulations and operating procedure for operation management.
- Entrusted management Designated personnel is entrusted for guard of Telemetering Station to prevent damages due to people, wildlife and livestock, etc.
- Attended operation, the system shall implement fixed personnel and fixed post to carry out attended operation work according to the code of practice. The personnel on duty shall supervise the working conditions of the system, and take measures for treatment as soon as possible for if finding problems.
- Routine maintenance.
- Regular and irregular inspection regular and irregular. Twice of comprehensive reviews of the system pre-flood and post-flood are generally conducted.
- Maintenance.

12.3.4 Staffing

To realize continuous operation and emergency treatment of the system during operation period by the operating personnel of the hydrological information automatic telemetry system, the allocated personnel of the center station is divided into two parts of regular technical support personnel and personnel on duty.

The regular technical support personnel is made up of computer communication and network professional, telemetering equipment maintenance personnel. The regular technical support personnel is mainly responsible for the normal and stable operation of computer, communication and telemetering equipment of the system.

The personnel on duty shall include hydrological professionals. The personnel on duty is mainly responsible for the forecast of hydrological information telemetry system, who shall also put forward suggestions for optimizing operation of hydropower station.
12.3.5 Scheme of tour gauging of flow and rating curve

Since the automatic flow test equipment may be affected by factors such as floater and silt, etc. when it is used in the natural river course, leading to high equipment failure rate and low test precision. So the hydrological stations in the natural river course generally obtain the relation between water level and flow of the cross section by using flow test, and obtain its flow in the way of converting the test water level into flow by automatic water level monitoring.

In order to facilitate the system operation, reduce the construction investment and downsize the operation personnel, the outflow hydrological stations shall be built according to the standards of tour gauging stations. Only the water level observation facilities and water level telemetering equipment will be built, while the production and living house, hydrographic cableway and flow test equipment will not be built. The flow test in this station adopts the way of tour gauging, and the Employer may entrust experienced professional team to test.

The flow test equipment of tour gauging station adopts the Acoustic Doppler Current Profilers (ADCP) to conduct the flow tour gauging, and the test method adopts the navigation type test method. The frequency of tour gauging and number of test shall guarantee the establishment of relation between water level and flow of cross section, it is preliminarily determined that the number of test per station per year is 50 times, the tester shall reasonably master the test opportunity to set the number of test, and try to avoid the time frame when there is many floaters in river so as to guarantee smooth progress of test. Draw up the relation between water level and flow according to the measured flow data. Try to choose the single-line alignment principle, when the foregoing principle cannot be met, consider to choose the scheme of temporary curve or loop rating and add the number of test.

Since the determination of the relation between water level and flow of tour gauging station requires a certain number of test, therefore, firstly measure the terrain of flow measurement section during construction of tour gauging station, and calculate the relation between water level and flow of tour gauging station with hydraulic formula, based on which to perform the preliminary forecast work, and use the relation between water level and flow of measured point rate location survey station with the increasing of number of test to improve the test precision of hydrological station.

Inquire into the flow process of cross section through continuous self-recording water level process in combination with the relation between water level and flow of cross section to provide original data for hydrological information telemetering forecasting work and ensure smooth implementation of hydrological information telemetering forecasting work.
13 Investment Estimation

13.1 Principle and basis of compilation and description

13.1.1 Compiling principle

The estimation of the system adopts other related quotas and fee standards involving profession and refer to the design fee standards of corresponding completed engineering in China, and the compilation is in accordance with the price level in 2010.

13.1.2 Basis of Compilation

- Hydrological Fundamental Facility Construction and Technical Equipment Standard (SL276-2002);
- Refer to the budget of hydrological information automatic telemetry system in China that has been constructed or under construction.

13.1.3 Compiling instructions

The budget estimate project of telemetry system includes civil engineering fee, equipment purchasing and installation fee, development fee of forecast software and other fees.

- The price of hardware and software equipment mainly considers the quotation from research & development unit, including freight and miscellaneous charges and fees for installation, commissioning and pilot run, and it is determined by also referring to the tender offers of tender of hydrological information automatic telemetry system of relevant hydropower stations. The water gauge shall adopt the bubble type water gage, and other main equipment shall adopts those produced in China;
- The investment of civil engineering shall be calculated by referring to the similar engineering recently;
- Since the equipment of hydrological information automatic telemetry system has unique characteristics, so calculate related costs according to actual situation;
- The construction expense estimate is only limited to the price level in the first quarter of 2015.
13.2 Estimate of total engineering investment

The total investment for construction of hydrological information telemetry system of Pak Beng HPP is $1,267,680.6, including $648,462.1 for equipment and installation, $205,161.3 for civil engineering fee and $298,813.5 for other items (mainly including design fee, construction and management fee, supervision fee, staff training cost and site service expense, etc.), the basic reserve fund is $115,243.7, and the operating cost during operation period is $590,662.3 per year. The construction budget estimate of hydrological information telemetry system of Pak Beng HPP is shown in Table 13.2-1, and the itemized investment is shown in Table 13.2-2.

It's important to note that the survey station of the project is located in Laos and Thailand, partial areas have relatively difficult conditions, insufficient building materials and inconvenient transportation, the investment of the hydrological information telemetry system has fully taken into consideration the above factors, this investment is only an estimate, and the actual investment shall be subject to the actual cost.

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Funds combined (USD)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Construction costs</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Equipment and installation expense</td>
<td>648,462.1</td>
<td>The construction cost of station house of Central Station, land and forest collection cost, negotiation charge with local departments and customs cost of related equipment are not included.</td>
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<td>Civil engineering cost</td>
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</tr>
<tr>
<td>3</td>
<td>Other expenses</td>
<td>298,813.5</td>
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</tr>
<tr>
<td>4</td>
<td>Basic reserve funds</td>
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</tr>
<tr>
<td>5</td>
<td>Total</td>
<td>1,267,680.6</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Operating cost during the construction (one year)</td>
<td>590,662.3</td>
<td></td>
</tr>
</tbody>
</table>
### Table 13.2-2 Item table of investment cost of hydrological information telemetry system of Pak Beng HPP during construction period

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Project name</th>
<th>Unit</th>
<th>Number</th>
<th>Unit price ($)</th>
<th>Amount ($)</th>
<th>Total ($)</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>Part I</td>
<td>Civil engineering fee</td>
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<td>205,161.3</td>
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<td>Telemetering Station</td>
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<td>Hydrological station</td>
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<td></td>
<td></td>
<td></td>
<td>112,903.2</td>
<td>Ban XiangKok, Ban Tung, Chiang Rai, Theong, Ban Houayxay and Namtha River HS in the system and Pak Beng HPP</td>
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<td>Observation road</td>
<td>Set</td>
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<td>56,451.6</td>
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<td>Hardened road surface, 1m in width</td>
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<td>Installation of rain gauge, antenna solar panel and lightning rod</td>
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<td>7,903.2</td>
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<td></td>
<td>Instrument chamber</td>
<td>Set</td>
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<td>16,935.5</td>
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<td></td>
<td>Fences</td>
<td>Set</td>
<td>7</td>
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<td>4,516.1</td>
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<td>Whole-brick wall, 2m×2 m×2.5m</td>
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<td>Bubble type pipe laying</td>
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<td>Water level station</td>
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<td>78,064.5</td>
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<td>KengPhaDai Station and upstream and downstream cofferdam, from town to Pak Beng</td>
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<td>Water gauge (including three benchmarks)</td>
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<td>4,838.7</td>
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<td>Amplitude of 25m</td>
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<td>4,516.1</td>
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<td>9,677.4</td>
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<td>The length is initially determined as 50m</td>
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<td>3,225.8</td>
<td></td>
<td>Excluding electronically controlled monitoring firewall</td>
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<td>Number</td>
<td>Unit price ($)</td>
<td>Amount ($)</td>
<td>Total ($)</td>
<td>Remarks</td>
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<td>-----------------------------------------------------------</td>
</tr>
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<td>Air conditioning</td>
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<td>Lightning protection equipment installation</td>
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<td>Lightning protection equipment of center station during construction period</td>
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<td>2</td>
<td>4,032.3</td>
<td>8,064.5</td>
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