# Technology and Benefits of the Hydrological Information Telemetry System on the Jinsha River

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**Abstract:** Since the cascade hydropower stations on the Jinsha River are developed from the downstream to the upstream, which are constructed in a whole and in stages, taking the operation period of downstream hydropower project and the construction period of upstream hydropower project being interrelated into consideration, this paper made a study on the hydrological information telemetry system on the Jinsha River in terms of scale, method of information acquisition, system structure, working mode, reliability and operation management based on the hydrometeorology, topographic and geological condition and current telemetry condition, so that the system can be planned, designed, constructed and managed as a whole as well as the information being shared. This paper also analyzed the benefits of the system based on a summary of the system operation and some examples (such as 2007's flood on the Heng River and rock fall in Xinshi Town due to torrential flood), which proves that the system is economical and practical as well as easy for management. The system can also satisfy the requirement both for the construction and operation of hydropower projects, which not only minimized loss and damage on the construction due to flood and storm but also improved telemetry capability of local departments.

**Key words:** Hydrological Information Telemetry System，Information Acquisition，Data Transmission Communication，Flood and Storm，Level of Automation

For the purpose to develop the rich water energy on Jinsha River and fulfill the national strategy of transferring electric power in West China to East China, it has been planned to construct four large-scale cascade hydropower stations at Wudongde, Baihetan, Xiluodu and Xiangjiaba, which have multiple benefits of power generating, flood control and irrigation. It is necessary to establish hydrological telemetry system on the lower Jinsha River with a view to collect real-time rainfall and flow information, make timely flow regime forecasts so as to provide scientific basis for safeguarding the dams from floods and for project construction and operation and reducing possible damage and losses caused by flooding and flash floods. The construction of such a system shall significantly enhance the flow telemetry automation level in local hydrological authorities and bring about social and economic benefits.

## 1.Layout of telemetry stations and system scale

### 1.1 Layout of telemetry stations

The system will be constructed in the intervening area from Shigu and Xiaodeshi to Yibin. The principle for telemetry station layout is that the long-term requirements of flow forecasting for construction of the cascade power plants on Lower Jinsha River shall be considered and the focus is to meet the requirements of flow forecasting with lead times of 24-48 hours during the period of construction of Xiluodu and Xiangjiaba projects; to meet the requirements of controlling the storm floods and preparing flow forecasting schemes; to make use of the existing national and local hydrological basic stations as much as possible; to save investment and easy for management. Therefore, the following aspects shall be considered when determining the telemetry station network.

(1) Hydrological stations should be deployed on the controlling river section of the hydropower plants so as to understand the flow variation process on the main stem and the tributaries. For the purpose to meet the overall requirement of flow forecasting with a 48- hour-lead time for the four cascade hydropower plants, hydrological control stations will be deployed on the main stem Jinsha river below Shigu and on tributaries of Yalong, Anning, Longchuan, Pudu, Niulan, Heishui, Meigu, Taliu, Sangyuan, Yupao, Xixi, Qingling, Dawen and Hengjiang rivers.

For the purpose to help provide hydrological forecasting service during project construction period and to accumulate data for the operation of dams as well as to provide basic data to check related design results, four special-purpose hydrological stations will be constructed at Wudongde, Baihetan, Xiluodu and Xiangjiaba. The collection items include water level, discharge, rainfall, water temperature, evaporation and sediment.

On the intervening area from Xiluodu to

Xiangjiaba, the water fall is great and the sediment concentration is high. Local storm rains can produce sudden and heavy floods with large volume and high peaks. Currently, there are basically no hydrological data between the two dam sites and there have encountered difficulties to check the original flood designs. Hydrological gauging sites should be deployed on the main tributaries on this intervening area.

(2) More densely rain gauging network should be established at areas near the dam sites so as to increase forecasting lead times and guarantee forecasting accuracy. On the main stem and tributaries on the intervening areas from Shigu to Yibin, in the economically developed areas and valleys with larger network density, due to the fact that the catchment areas are not large, the runoff production is relatively limited, which has no big impacts on flood forecasting. Thus appropriate dense network is suitable. In the reservoir areas on the upper stream of tributaries, due to the impact of reservoir impoundment, the original runoff production and flow concentration pattern have long been disrupted. Attention can be put on understanding reservoir storage and discharging. As for rainfalls on reservoir areas, a slight idea of them is enough. In areas of the main stem and on the middle and lower reaches of the tributaries, the network can be established according to the principle of even distribution and all the existing areal rain gauges with relatively good conditions can be integrated into this system. For areas with sparse network or local areas with no gauging sites, rainfall gauges should be added. In areas near the dam sites, more densely rainfall networks should be deployed with a view to increase forecasting lead times and guarantee forecasting accuracy.

(3) Temporary water level stations should be deployed in dam site area to provide basis for flood control and emergency handling. In areas within 20km of the dam site, water level stations should be established to control the water surface profile and horizontal slope in the construction areas. At key location of the project, such as below and above cofferdams, at inlet and outlet of diversion tunnel, above and below the dam, special-purpose hydrological stations should be deployed to understand the water level variation in a real-time manner.

**1.2 Project scale**

Through analysis and justification, the hydrological telemetry system is determined to be composed of 32 hydrological stations, three water level stations, 123 rainfall stations and 12 special-purpose water level stations. Due to the fact that in local regions of Jinsha River basin the precipitation is affected to a significant scale by topography, the spatial distribution is uneven, the rain gauging network is a bit sparse. In the days that follow, the telemetry network can be supplemented and made perfect on basis of the accumulated data and operational forecasting and for satisfying the needs of flow forecasting during the construction periods.

The system central station is set at Xiluodu hydropower plant, and the subcentral stations are set at Wudongde, Baihetan and Xiangjiaba hydropower plants. In the light of the fact that the covering area of the telemetry system is wide with many gauging sites, and the telemetry stations are constructed on basis of the existing hydrological stations, it is determined to set up within the area of the telemetry system nine operation and maintenance subcenters and one operation and maintenance coordination center. To sum up, the system is composed of one central station, three subcentral stations, 9 operation and maintenance subcenters, one operation and maintenance coordination center and 170 telemetry sites.

## 2 cheme for communication networking

The to-be-constructed telemetry system is located in areas of Qinghai-Tibet Plateau, Yunnan-Guizhou Plateau and the western boundary of Sichuan Basin, which belongs to the terrain of plateau. The telemetry sites are mainly located in Yuannan and Sichuan provinces, and the rain gauges are mainly located in the remote regions where the economy is under developed. Therefore, the scheme for communication networking is determined by considering the actual requirements of flow information transmission, by taking into account of the natural conditions in the river basin, the existing communications resources and the power supply situation and by comparing the reliability of the communications channels, the transmission quality, system investment, operation and management.

### 2.1 Comparison and analysis of communications modes

For the purpose to understand the situation of available communications resources and the communications quality of available channels, telemetry site investigation and communications channel tests have been carried out. Field tests show that the communications success rates of Inmarsat C, Beidou Telecommunication Satellite, GSM short messaging, GPRS and PSTN are 99.4%, 100%, 81.6%, 40.5% and 79.7% respectively.

Through comprehensively analyzing the properties of the each communication channel and by considering the field test results, the communication pattern for this system is determined as follows.

(1) Satellite communications has the property of good transmission quality, no limitation on transmission distance, large covering area, being less subject to impacts of topography and climate and flexibility in networking. Seen from the similar hydrological telemetry systems constructed in the upper Changjiang River basin, though the costs for terminal equipment and system operation of satellite communication are higher than that of the other communication patterns, the reliability and time efficiency of satellite communication are far higher than that of others. Currently the commonly used are Inmarsat C and Beidou Telecommunication Satellite. The Beidou Telecommunication Satellite has the properties of large capacity, fast transmission rate, lower communication cost than that of other satellites and it therefore has significant advantage to be used in large-scale hydrological telemetry systems. In addition, seen from field communication channel test results, the communication quality at all the sites

of this system by Beidou Telecommunication Satellite can satisfy the requirement. Therefore, the Beidou Telecommunication Satellite is chosen as the primary data transmission communication channel in this system.

(2) PSTN communication has the advantages of fast transmission rate and large capacity. For those hydrological and water level stations where PSTN has already been installed and field tests show the communication quality can satisfy the requirements, the PSTN is chosen as the backup channel.

(3) For those hydrological, water level and important rain gauges, if the PSTN channel cannot satisfy the requirement, then the GSM short messaging communication will be chosen as the backup channel.

### 2.2 Determination of system networking mode

According to the communication channel test results for each telemetry site, and by considering the importance of the flow data at each site in flow forecasting, the principle for communication channel deployment from the telemetry sites to the central station is as follows: the dual primary and backup communication channels are employed for all the hydrological and water level sites and for those rain gauging sites located in the river basin below Huatan and the primary and backup channels can switch over automatically. For those rain gauging sites in the river basin above Huatan, only single channel is employed.

The scheme for system communication networking is as follows: for the hydrological and water level stations, the Beidou Telecommunication Satellite and the PSTN or the Beidou Telecommunication Satellite and GSM short messaging are employed, and both communication channels are mutual backup and can switch over automatically. For those rain gauging sites in the river basin below Huatan, the Beidou Telecommunication Satellite and GSM short messaging are employed, both communication channels are mutual backup and can switch over automatically. For those rain gauging sites in the river basin above Huatan, the Beidou Telecommunication Satellite are employed.

## 3 Working mode

The commonly used working mode for hydrological telemetry systems are timed/event reporting mode, polling mode and mixed mode. According to system requirement, the working mode of this system is a combination of timed reporting, event-triggered reporting, and polling, which has the function of in-situ and remote programming.

## 4 System structure and information flow chart

Considering the economical reasonability of system construction, operation and maintenance, we have analyzed and justified the system structure and information flow chart, which are determined and shown as in Figure 1 and 2. The satellite communication has the function of one-point transmission and multiple-point reception, which can satisfy the overall requirement of the telemetry sites transmit data and the central station, the subcentral stations and the operation and maintenance subcentres can receive the data simultaneously. That is to say, the system central station and the subcentral stations can receive flow and rainfall information from all the telemetry sites in a real-time manner; at the same time, the operation and maintenance subcentres, which are located in local hydrological authorities can also receive flow and rainfall information from the telemetry sites under its management in a real-time manner.

The main information in the system includes rainfall, water level and discharge (manually input). When changes in flow and rainfall occur or when it gets to timed times, each telemetry station will automatically collect the flow and rainfall information, then automatically transmit via the data transmission network composed of satellite, PSTN or GSM short messaging. The central station and the subcentral stations can receive all the information in the entire system. After being processed, the data will be forwarded into the real-time database, and then be used by flow forecasting subsystem and other information service systems. The central station can supervise the telemetry stations. The central station and subcentral stations can exchange and share information resources via the network. Should malfunctions occur in the central station, the subcentral stations can receive information from the telemetry station under its management. The subcentral stations can work as data backup stations at locations different from the central station. The operation and maintenance subcentres can receive information from the telemetry sites under its management. Data are processed and then entered into real-time databases, on basis of which, the subcentres can monitor the working status of the telemetry stations.

## 5 Information acquisition techniques

(1) Rainfall collection

The rainfall measurements are automatically collected, stored in the field and then transmitted by wire to a short distance away. The telemetry rainfall stations can operate in a mode of being kept an eye on but unattended. In the light of the annual average precipitation amount and the rainfall intensity variation property in the river basin of the system, all the rain gauges are chosen to be the tipping-bucket rain gauge with a resolution of 0.5mm.

(2) Water level collection

The water level measurements should realize automatic collection, solid-state memory storage and short-distance transmission. According to field investigation and analysis and justification, at those hydrological and water level stations where water level observation wells can be built, or have already existed, the float-type water level recorders will be used. At the remaining stations, the pressure type water level recorder will be used. In the light of gas supply situation, those pressure type water level recorders that are with external gas supply or with pumps will be applied.

(3) Discharge measurement

At the hydrological stations in the system, discharge measurements will be made by applying the existing facilities and using the existing methods. By using a manual data input device, the discharge values will be entered manually, into the telemetry terminal, stored and transmitted to the operation and maintenance subcentres, the subcentral stations and the central station.

## 6 Integrated technique of data collection, data transmission and control at telemetry stations

In order to guarantee the reliable and effective operation of the system, construction of the telemetry stations should make use of the latest telemetry technology, modern communications technology and remote programming control technology and the structure design should be such that data collection, data transmission and control are integrated. Based on the SCADA or RTU, data collection, preprocessing, storage, transmission as well as the receiving and sending of control commands can be realized. The integrated telemetry stations are mainly composed of the sensors, remote telemetry unit, communications terminal, manual data input device and power supply. The structure is shown in Figure 3. The integrated telemetry stations have functions of automatic collection of rainfall and water level measurements, timed reporting, event reporting, interrogation and response, field solid-state memory storage, manual data input, field data display, field or remote programming. They can operate under bad weather conditions.

## 7 Measures of reliability

The major indexes to indicate the reliability of hydrological telemetry systems are the mean time before failure (MTBF) of the system devices and the data transmission unblocked rate of the system. The factors affecting the reliability of the system are mainly grounding, lightening protection, power supply and the reliability of communications channels.

### 7.1 Lightening protection and grounding

Due to the fact that direct thunder hitting has enormous energy that can bring about significant damages to the devices, lightening rod and lightening grounding technologies are used to divert the lightening current to the ground so as to avoid lightening hitting the buildings and devices directly.

At each telemetry site, grounding and lightening rod are installed to protect the instrument box, antenna, solar panel from lightening hitting. At the telemetry site, the grounding resistance should be less than 10Ωwhile it should be less than 5Ω at the central station, the subcentral stations and the operation and maintenance subcentres.

**7.2 Lightening protection**

The devices in the telemetry stations are often damaged by the induction thunders. Generally speaking, the induction thunders are not so fierce as the direct lightening strikes, but the occurrence probability of induction thunders are much larger than the direct lightening strikes. Normally one lightening strike can cause overvoltage in a large area. The induction high voltage can transmit far away via the electric power lines and telephone lines, which can cause the disastrous area to expand. In this system the following specific measures are taken to protect the devices from the induction thunders.

(1) The cables for water level and rainfall signal transmission are first put into zinc plated steel tubes and then buried underground, avoiding suspension in the air. The shielded layer of the signal cables are connected with the grounding cable of the remote sensing terminal.

(2) Lightening arrestors are installed at the water level and rainfall signal input end to the remote sensing terminal.

(3) When the PSTN channel is used for data transmission, the telephone line lightening arrestors are installed and well grounded so as to guarantee uninterrupted communications and safety of the devices. For those telemetry sites where lightening occurs frequently, multiple stages of telephone line lightening arrestors are installed.

(4) When the VHF channels are used for data transmission, coaxial lightening arrestors are installed to protect lightening induced by antenna feeders.

(5) Between the recharging cable and the recharging controller of the solar panel direct current lightening arrestors are installed.

(6) With alternating current power supply, the lightening arrestors with large discharging capacity and fast response will be installed for the power supply cables. The discharge capacity of the lightening arrestors should not be less than 10KA.

**7.3 Power supply**

(1) Power supply to the telemetry stations

In order to ensure the equipment at the telemetry sites can operate reliably and normally under bad conditions of lightening, storm rains and breakdown of power supply, the telemetry stations will be powered by direct current from the solar panel battery with floating recharging. The battery should have such a capacity that it can ensure power supply to the equipment even after 45 overcast and rainy days in succession and be able to be recharged full during 10 to 20 days. The battery capacity and the solar panel power needed at the telemetry stations will be determined according to the power consumption of the equipment and the annual days of sunshine at the location of each telemetry station.

(2) Power supply to the central station, the subcentral stations and the operation and maintenance subcentres

At the central station, the subcentral stations and the operation and maintenance subcentres, the data receiving and communications equipment will all be supplied with power by the batteries that are recharged by alternating current. The computer network equipment will be supplied with power by UPS to ensure data receiving even under conditions of AC power supply breakdown. All the other equipment will be supplied with power by the alternating current with instantaneous voltage suppression.

**7.4 Reliability of communications channels**

The practices of already built systems show that the application of dual channels that are mutual backup to each other and can switchover automatically is the fundamental measures to guarantee the data transmission unblocked rate. Therefore, the design scheme of dual channels that are mutual backup to each other and can switchover automatically has been applied in this system.

**8 System initial operation benefits**

After the hydrological telemetry system in Lower Jinsha River basin for development of the cascade hydropower stations has been constructed, the system is managed in such a pattern that the operation and maintenance of the telemetry stations are entrusted to the related local hydrological authorities, while the operation and maintenance of the central station and the subcentral stations are entrusted to the qualified units, the owner of the system takes the charge of unified coordination and management. Since the system has been put into operation, statistic data show that the data transmission unblocked rate of the system is ≥95％, the flow and rainfall information collected at the telemetry stations can be transmitted to the central station, the subcentral stations and the operation and maintenance subcentres within ten minutes, which has made it possible to understand the changes in flow and rainfall regime timely and the variations in storm centers and rainfall intensity. Timely flow and rainfall information has been provided for the safe construction of hydropower stations and for local flood control, which has produced fairly good flood control benefit and economic benefits.

**8.1 It has provided scientific basis for project construction and operation decision-making**

After the hydrological telemetry system in Lower Jinsha River basin has been completed, the flow and rainfall information within 24 hours of flow concentration time in all the telemetry stations above the dam sites and those information within 48 hours of flow concentration time in the important telemetry stations can be collected accurately and in a real-time manner, which can provide real-time data for flood forecasting during the construction periods, increase flood forecasting lead time and play an important role in flood prevention during periods of construction of cofferdams, diversion tunnels, river closure and dam concrete placement. It has provided scientific basis for project construction and operation decision making, reduced damages and losses from floods and flash flooding disasters and guaranteed the projects to be implemented on schedule. Meanwhile, the real-time data collected at dam sites can be used to check the hydrological conditions for project design, which can accumulate data for project operation and management after the projects have been completed.

**8.2 It has played an important role in preventing flash flooding disasters.**

In August 2007, a heavy flood of 20 years in return period occurred on Hengjiang River. The hydrological telemetry system in the Lower Jinsha River basin has played a positive role in flood control and flash flooding disaster reduction. The rainfall information collected by the system showed that on August 16, the rainfall amount at Mugan site during six hours from 2:00 to 8:00 reached 163.0mm, while in the nearby areas, except at Doushaguan hydrological station where the daily rainfall amount exceeded 20.0mm, at all the other sites, there were no rainfalls or with rainfall amount less than 10.0mm. One local hydrological authority made analysis on the collected information and concluded that it was a typical sing point storm rain. They immediately formulated a flow briefing and forwarded this important information to the local government and Yunnan provincial flood control headquarters. The Yunnan provincial flood control headquarters immediately judged that it was probable that slide flows should occur in this region and then initiated the emergency response process to avoid the disasters and arranged emergency handling and disaster relief works, which has effectively reduced the damage and loss in people's life and properties.

**8.3 It has provided information support for flood control activities.**

The hydrological telemetry system in the Lower Jinsha River basin has increased the automation level of local hydrological authorities and enhanced their capabilities to monitor flow and rainfall regimes. It has provided information support for local flood control authorities to prevent flood and reduce disaster loss. During the period from July 24 to 25, 2007, heavy storm rains fell in the intervening area from Xiluodu to Xiangjiaba. Rock slides occurred at the entrance of Xinshi Town tunnel, which was an auxiliary road to the Xiluodu hydropower station. The flow and rainfall information collected by the system showed the rainfall amount at Oujiacun station and Longshan station, which were near Xinshi Town during the period from 8:00 on July 24 to 8:00 on July 25 reached 119.6mm and 136.0mm respectively, in which the rainfall amount at Longshancun station during the period from 0:00 to 1:00 of July 24 was 28.6mm, which reached the storm rain standard. The hydrological authority immediately forwarded this information to the local government, which immediately evacuated inhabitants, avoiding losses of people's lives.

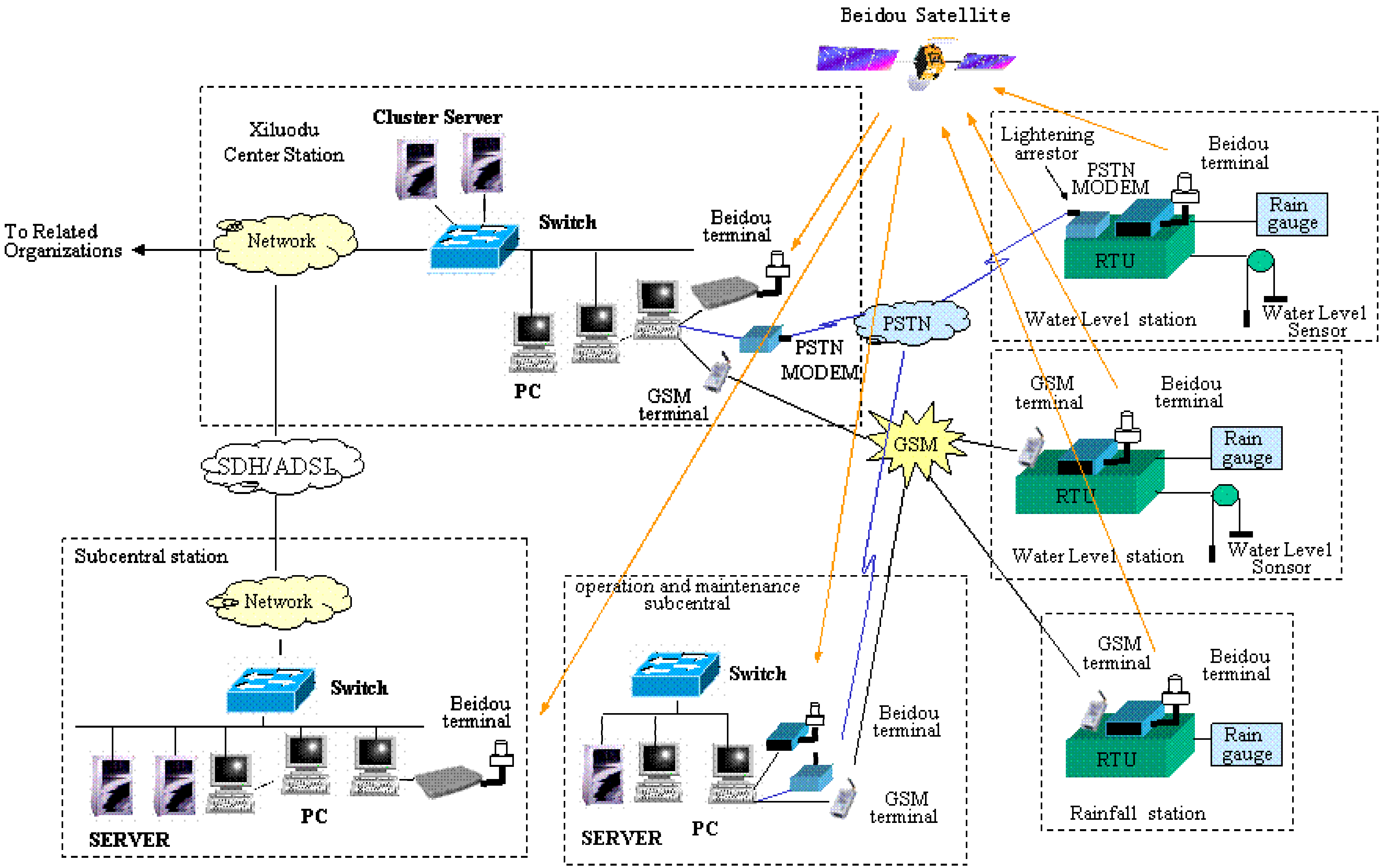


Fig.1 Structure Block Diagram of the Hydrological Information Telemetry System on the Jinsha River

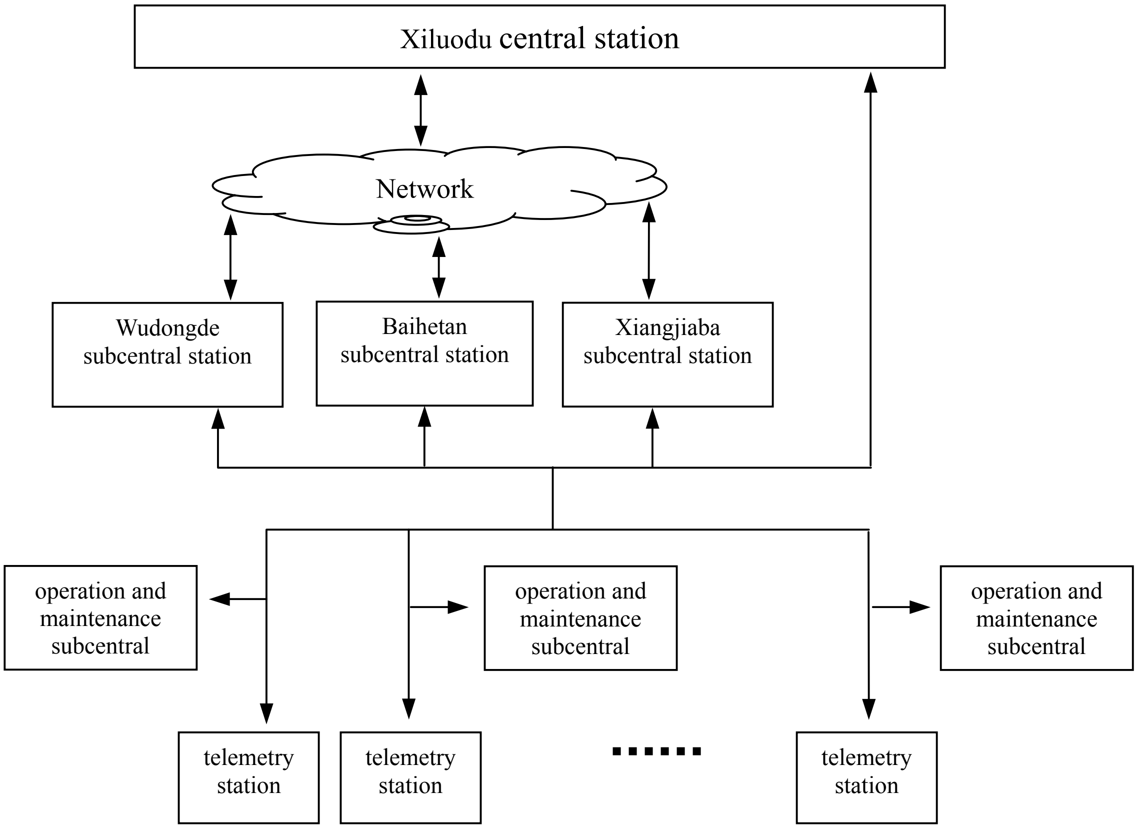


Fig. 2 Block Diagram of the System Information Flow Chart

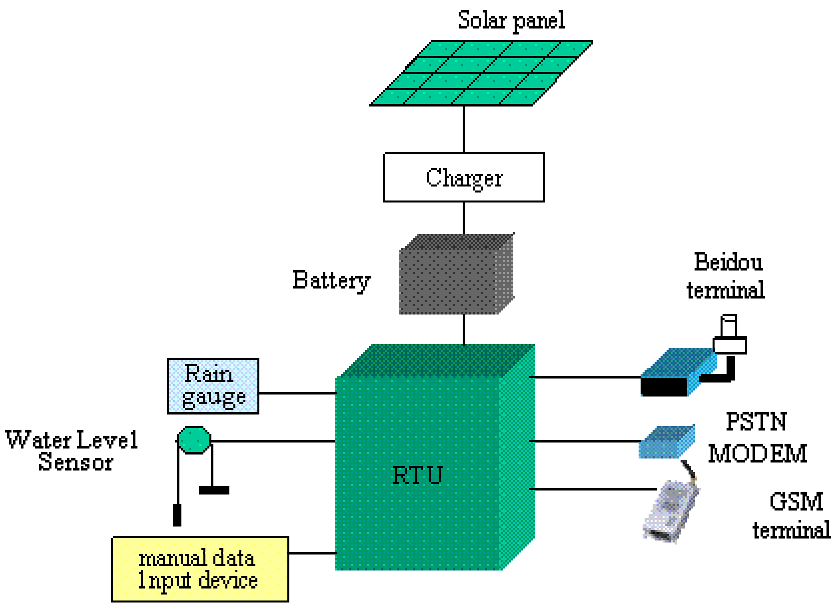


Fig.3 Structure Block Diagram of the Telemetry Station