RESEARCH OF AUTOMATIC MONITORING SYSTEM OF RESERVOIR BASED ON EMBEDDED SYSTEM

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Abstract: The automatic monitoring system of reservoir is an important means to realize modernization of reservoir management. This paper expounds the structure of automatic monitoring system of reservoir firstly. The system consists of three subsystems, which are acquisition subsystem , transmission subsystem and data management subsystem. Secondly , the design of the data collection terminal is studied, which realized the design of hydrological data collection terminal including hardware design based on embedded system and software design. The reason that affects data collection is analyzed and anti-jamming measures are given. And then the system structure of data transmission is offered, and the transmission mechanism of mixed-mode network, in which the elementary channel is wireless mobile communication and the backup channel is wire communication, is achieved. Finally, the data management subsystem is briefly introduced. The system is proved to be useful and efficient by the application on Xueye Reservoir.

Keywords: monitoring system of reservoir, embedded system, data collection

1. STRUCTURE OF AUTOMATIC MONITORING SYSTEM OF RESERVOIR

Reservoirs are important water conservancy facilities and water resources protection bases. They are key facilities which ensure industrial and agricultural production and urban people's life. Also, they are foreland of the rapid response to flood prevention, drought control and flood warning. The management level of reservoir is directly related to the normal design efficiency and people's life and property's safety. As the main contents of the reservoir modernization, reservoir automatic monitoring system can realize the automatic collection and delivery of hydrological factors such as rainfall, water level and water scheduling, directly serve the flood forecasting and scheduling and the water resources management, achieve the optimal allocation of water resources, provide the scientific basis for decision-making on the efficient use of water resources, comprehensively upgrade the management level of the reservoir, and is an important means to realize reservoir management modernization(Liang et al., 2005).

Reservoir has become main water source of agricultural. But with rapid development of country economy and society, the conflict of water supply and consume stands out increasingly (Liu, 2004). The lack of water resource has touched our foodstuff directly. The foodstuff output reduces 700 hundred million to 800 hundred million every year due to lack of water. Along with population growth and industry development, the contradiction of water lack will be more outstanding. So saving agricultural water is imperative under the situation, while rebuild conventional management measures and irrigation establishments are essential instruments to realize water saving.

Reservoir automatic monitoring system consists of data collection subsystem, data transmission subsystem and data management subsystem.

Data collection subsystem includes the gate open degrees collection terminals, rainfall collection terminal, water level collection terminal, power output collection terminal, industrial water collection terminals and data center. Data collection subsystem mainly completes the automatic collection of hydrological information including water level, rain and flow, and the data center exchanges data with collection terminals through the GPRS network. Data transmission subsystem is a mixed-mode network, which uses wireless mobile communications (GPRS) as the main channel and cable communications (PSTN) as a backup channel. It is responsible for transmitting the collected data to the database of data center. Data management subsystem uses SQL Server as the data management platform for data inputting, deletion, modification, storage, retrieval, sorting and statistics management. Figure 1 shows the structure of automatic monitoring system of reservoir.

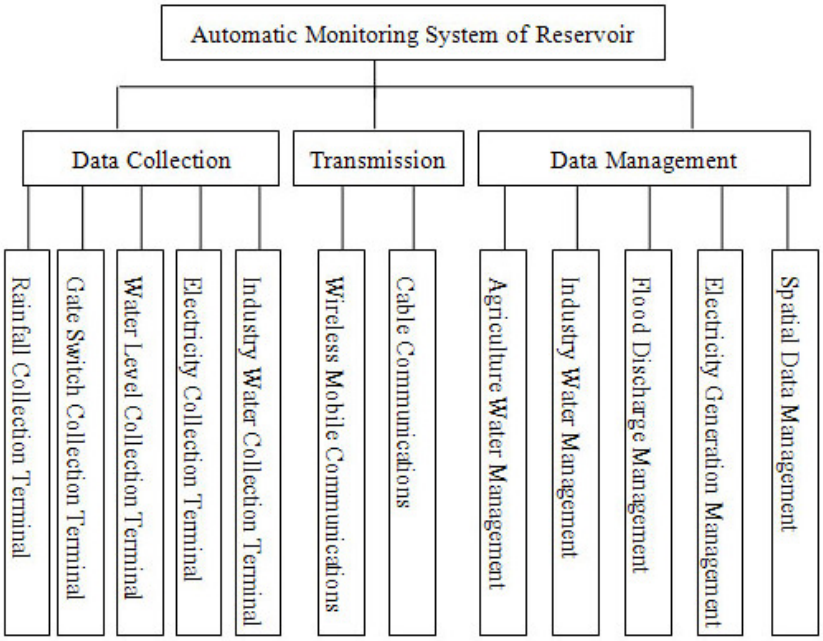

Figure 1. Structure of automatic monitoring system of reservoir

2. THE HARDWARE DESIGN OF SYSTEM

Hardware includes the hardware which is installed at the information control and transaction center, and rainfall collection terminals, irrigation flow collection terminals, reservoir water level collection terminals.

2.1 Data Collection Terminal

Data collection terminals are designed with embedded system. They have the following main features: stable and reliable operation, low power consumption, large storage capacity; high operational speed to deal with complex algorithms and protocols quickly. They also can be connected to Internet and use public networks for data transmission, cost low communication, and realize data on-line monitoring completely (Ye et al., 2007; Shi et al., 2007; Shen, 2007).

LPC2294 processor is used for data collection terminals. An embedded system platform is constructed by making use of the excellent core performance and the abundant external interfaces of LPC2294, which create

data collection terminals. The hardware structure of terminals is shown in figure 2.

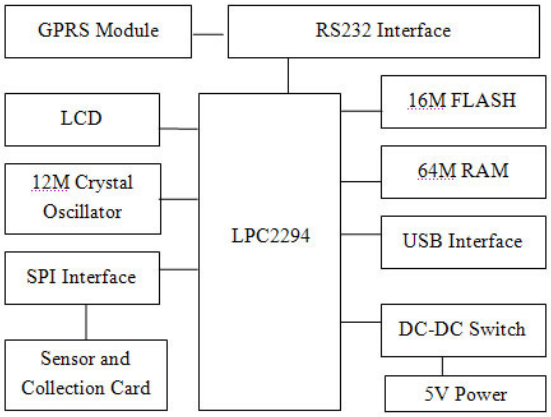

Figure 2. Data Collection Card

The processor LPC2294 used in collection terminal is 32 bits ARM7TDMI - S CPU which supports real-time simulation and tracking. With the 256 KB high-speed flash memory, 128 bits width memory interface and the unique accelerating structure, 32 bits code can run at the maximum clock rate. 5 V to 3.3 V and 3.3V to 1.8V DC-DC converters in power circuit can supply power to LPC2294 and the other external circuits that need 3.3 V.

A 12 MHz oscillator is taken as the system clock for the LPC2294 chip, and the internal clock which controls logic can produce different frequency clock signals that the system needed. FLASH memory can store boot loader, embedded operating system, application procedures and the user data need to preserve after the system restarts. RAM memory is the system's main regions, where the operating system, user data and stacks are located. The system connects to GPRS modules through an RS232 serial link in order to finish wireless data transmission functions. The system expands IO modules through SPI interface, which links hydrological collection equipment sensor and collection card and completes inputting and outputting of digital and analog signals.

2.2 Anti-jamming technology

Data collection terminals installed in the field are often influenced by electromagnetic fields, lightning, electrostatic, switching power supply, motor starting current and other noise impact. These factors will affect the reliability and safety of whole system, and result in increasing of data collection errors, controlling state failure and procedures disorders.

Therefore, these factors must be taken into account during the design of the system.

1. Because the control output circuit load of system is relays, contactors, and other inductive load, high induced electromotive force (EMF) will be produced in inductance coils when they disconnected. This high EMF can not only cause interference electromagnetic induction in circuitry, but also cause spark or arc interference between contacts that affecting the normal work of microcontroller, or even "dies" phenomenon. This problem can be effectively solved by adding discharge diode parallel absorption device at both ends of the relay J coil.

2. Data terminals installed perennially at the field are vulnerable to the wind, the sun, the rain, the lightning and overload factors. The most important issue in terminals design is reliability in the harsh environment. In order to solve the problems, the following measures have been adopted.

(1) All the hardware chips are the wide-temperate chips used in industry which adopted CMOS low-power structure with good anti-interference capability and very low power consumption.

(2) In the layout design of PCB, the signal collection line, the memory data bus and control bus adopt the parallel multi-lane surrounded with a large area of land lines. The critical data lines will be siege by all land lines and TVS tubes are added between the data bus and the large area of land lines, which can absorb the over voltage. A very clear anti-jamming effect has received through above-mentioned measures.

(3) In addition to high power or heating devices, all components used patch components. At this stage, patch components production need a high technological level, so there is little fake patch components. At the same time, patch components are small and easy to integration. The stability and reliability of the system is further enhanced by using hot air returned exclusive automatic welding equipment that can prevent the welding from damaging chips.

(4) A specially designed waterproof aluminum alloy frames is adopted. The outlet lines are four-core shielded twisted paired, the plugs use waterproof jacks and the twisted paired lines use the sensor end grounding method. All the methods can avoid the interference from outside stray electromagnetic field.

3. Sometimes the system program may come into a "cycle of death" due to interference, that is, the system procedures lost control. Software anti-jamming technology such as directive redundancy and software traps can not make these procedures from "death cycle." Surveillance procedures, also known as the "watchdog" technology, can prevent the process from the "death cycle". "Watchdog" technology is constantly monitoring procedures orderly running time. If the time is longer than the known cycle time, the procedure will be considered to be trapped in a "cycle of death" and then

forced it to return to the 0000H procedures entrance where a wrong procedure is arranged that allow the system to run onto the right track.

2.3 Distribution of data Collection Terminal

Data Collection Terminals include rainfall collection terminals, irrigation flow collection terminals, reservoir water level collection terminals, gate opening collection terminals and industrial water collection terminals.

Rainfall collection terminals distribute in Chaye rainfall stations, Shangyou rainfall stations, Longzi rainfall stations, Luye rainfall stations, Yumen rainfall stations, Xueye rainfall stations, Kouzhen rainfall stations, Qiguanzhuang rainfall stations, Huzhai rainfall stations and Gushan rainfall stations. The rainfall tubes used in these stations are telemetry dedicated rainfall gauges with a resolution of 0.5 mm.

Irrigation flow collection terminals distribute in the main channel, the eastern entry, the western entry, Hebei-Sanshan junction, the Sanshan-Kouzhen junction, the Kouzhen-Qiguanzhuang junction, the Qiguanzhuang-Heguanzhuang junction and the Heguanzhuang-Huzhai junction. The ultrasonic sensors are used to measure the channel depth that will be converted into the flow values to calculate the flow.

Reservoir water level collection terminals installed a platform with the altitude of 231.30m in the west side of the dam. A large-range ultrasonic sensor with the measuring range of 20 meters is installed at the height of 231.70m. The minimum measurable height is 211.70m, which is lower than the dead storage water level, so it fully meets the range requirements of water level.

There are six telemetry gate opening collection terminals: the main flood discharge gate, the 1st and 2nd sluice of irrigation area, the 1st gate of irrigation area, the eastern entry, the western entry. Photoelectric rotary encoders are adopted as the gate opening sensors.

Telemetry industrial water collection terminals are Laiwu power plant, Laicheng district power plant and Xueyin Company. Ultrasonic flow meters are installed in these units, and the RS485 interfaces are taken as the data collection terminals which transmit the collected data.

2.4 Remote Controller of Floodgate

The main function of remote controller on open-close degree of floodgate is to receive floodgate control signal from data center to open and close floodgate according to control information. The remote controller on open-close degree of floodgate is composed of GPRS wireless data terminal, data analysis and processing circuit, floodgate up and down circuit, direction shift

delay circuit, over load and over flow protection circuit. Figure 3 is the graph of remote controller of floodgate.

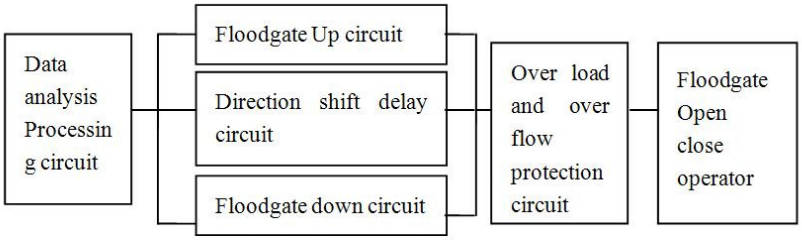

Figure 3. Remote controller of floodgate

3. DATA TRANSMISSION MODE

3.1 Transmission Network

According to the availability of current domestic communication resources and the actual situation and also taking the operational management facilities of the system into account, a mixed-mode network is designed with the use of wireless mobile communications as the main channel and the cable communications (PSTN) as a backup channel. Equipped with the "double channel", the communication can be automatically switched to the backup channel in case of the main channel failure, and return to the main channel to transmit data after the main channel is normal again(Guo et al., 2007; Liu et al., 2006). Because all the stations are situated in the coverage areas of China Mobile's signal, the wireless mobile communications are taken as the main channel. Data are packaged into TCP / IP data packets in the GPRS modules of data collection terminals and are sent to the data-processing and control center through the GPRS wireless network (Li et al., 2004; Cui, 2004). Transmission network is shown in figure 4.

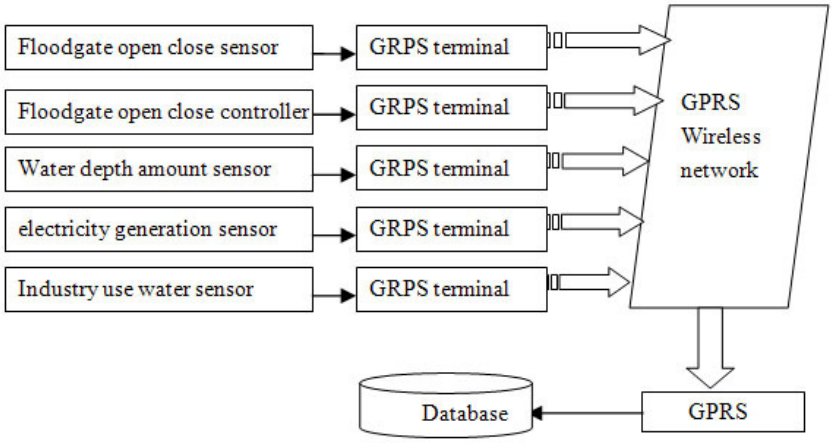

Figure 4. Transmission Network

GPRS modules adopted H7000 produced by Hongdian Company in Shenzhen. The unified mobile SIM cards are required to install in each module of collection points, and has the only ID in the mobile network just as the mobile phone. Specialized APN distributed by China Mobile is adopted by GPRS wireless data terminals and control center to access the wireless network. There are four modes for H7000 GPRS wireless DDN System, and different stations can choose arbitrary one mode according to the actual situation (Wu et al., 2007).

(1) Always-on-line mode

Always-on-line mode will maintain DTU model and data center connections. Its work is: DTU connects to GPRS network automatically when it boots. Connect automatically according to the IP address of data operations center (DSC), and maintain and preserve the connecting link. DTU monitors the operation of link of the network, and automatically re-establish link once the exceptions occur.

Rainfall measuring stations are used to measure rainfall, the water level and water from the upper reaches of the river measuring stations are used to measure the water level in the reservoir and the upper reaches of the river water level. So, they are continuously working methods and GPRS modules in these stations use this mode.

(2) Regular transfer mode

DTU uses regularly transfer mode to send data to the center regularly. Its work is to send and receive data to data center operations (DSC) according to the pre-set interval. After it's over, automatically disconnect.

Pressure tube water level measuring stations are used to measure the water level of pressure tube of the dam every week. GPRS module in these stations can choose this mode for this is a cycle of work.

(3) Data triggered mode

In this mode, the DTU initiates link only when the user need to transmit data. DTU connects to GPRS network and logs data operations center (DSC), and the data are transmitted.

Gate opening measuring stations measure the opened extent of gate and will be used only in agricultural irrigation and flood. Water level measuring stations measure the water level of agricultural irrigation channels in irrigation areas and use only in agricultural irrigation work. These stations can choose this mode.

(4) Center call mode

Center call mode is used for transmitting data to the DTU from data center. The data center sends a data transmission request and the DTU responses and transmits data to operations center (DSC) according to the instructions of DSC.

(5) Dormancy mode

If there is no data transmission, wireless transmission system will be closed and come into a state of dormancy. Apart from rainfall stations, other stations in the system will be in this state if there is nothing.

3.2 Communication Protocol Design

There is a set of stringent response mechanism when transmit data using TCP / IP. The headers of TCP are longer than the telemetry data when the TCP is used for transmission. When the responsive signal sending from the receiving party is not received, the transmission party will be repeated sending until the responses received. If the TCP protocol used for telemetry data transmission, and transmission efficiency will be substantially reduced. However, UDP network broadcasting agreements don't have the response agreement, and not suitable for high reliability telemetry data transmission. Therefore, According to water telemetry system characteristics, the data packets of the system use the first two bytes for station number, then after a number of byte values for telemetry, the last byte for CRC. Before the station sends the data, the first is to connect data center with IP connectivity, and transmit data directly without sending request signals, and then wait for sending the responsive signal from the data center. When the survey station didn't receive response signals from the data center after delaying time, sent again, and then waited for the response from the data center. Such repeated

three times. It proves that the agreement is fully in response to satisfy the requirements of the telemetry system.

4. DATA MANAGEMENT

The main function of data management subsystem is to store the attribute data and spatial data, that is, to input, delete, modify, store, retrieve, sort and do statistics.

The attribute database management system mainly managed many data closely relating to the objective function in the form of database, such as text, tables and so on. Attribute data included: water characteristics, such as rivers data, hydrological station distribution and rainfall distribution; reservoir information, such as reservoir characteristics, water-storage capacity curve, inflow, the water level at the dam, the flow out; hydrological information, such as daily flow, the water level information; meteorological information, such as precipitation, temperature, wind speed, air humidity, evaporation, sunshine and vapor pressure; water consumption information, such as water for agricultural, urban water supply, the local industrial water consumption and hydropower; reservoir scheduling information, such as water scheduling information, flood scheduling information, optimum scheduling information.

Geographical information system is based on spatial database. When establishing spatial database, layered technology is used to separate a variety of geographic elements into a number of independent layers, establish the relationship between physical objects and geometric characteristics in order to edit, hide and display, select and analyze. spatial database, such as 1:10 terrain database, the database of geographical names, land used classification map, river map, project distribution maps, digital elevation and so on, is built based on 0.6-meter satellite image shot in 2005 and consulting 10,000 maps, and the input of the spatial data (such as irrigation, drainage and irrigation stations, a field distribution) relating to irrigation management business is completed, and then the function such as the changes of spatial reference, spatial analysis, the inquiry and display of the feature elements, the exports of electronic maps and so on, is achieved.

5. CONCLUSIONS

The automatic monitoring system of reservoir has been put into use in Xueye reservoir, Laiwu City, Shandong Province. The system completes real-time data collection, transmission and automatic management. It is timely, efficient, accurate, and has low operating cost. Managers can grasp

the reservoir information immediately and accurately so as to take proper measures to regulate the water resources reasonably. According to the results, we can see, the system can provide detailed and accurate hydrological information in time, and can provide decision-making basis and reliable information for reasonable water schedule and scientific flood control, which is proved to have significant social benefits and great economic benefits.

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