Remote Monitoring System Based on GPRS

A Case Study for Water Withdrawal

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Abstract—**In order to realize supervision of water withdrawal, it is necessary to establish a modern remote monitoring system. This study focuses on the design of a remote monitoring terminal system that is operating in a south province in China. This terminal system adopts GPRS mode to establish communication with monitoring center. Detailed hardware design is provided, as well as its software functions. This terminal device finishes the basic function of water quantity collection. At the meantime, remote upgrade function and picture collection function are proposed in order to perfect the overall functions of the system. Kinds of tests were conducted to verify its performances and functionalities. We conclude that the proposed remote monitoring terminal might become a useful tool for supervision of water withdrawal in the dispersed areas.**

Index Terms—**Remote monitoring, Water withdrawal, Water quantity, RTU, GPRS**

I. INTRODUCTION

Water is a limited natural resource and a public good fundamental for life and health. Along with the rapid development of state economy construction and process of urbanization, the water use and the demand for higher water quality have increased, too, for drinking and domestic use, fisheries, agriculture, navigation, cooling of power plants, hydropower generation and recreational activities [1].

Water withdrawal, referring to water removed from the ground or diverted from a surface-water source for use [2], is the main source of water for life and industry. In many areas of China, due to the lack of effective monitoring means, the use of water withdrawal has many loopholes, which lead to the waste of water resources. With the promotion and implementation of the most stringent water management system in China, it is important to pay attention to the supervision and management in terms of exploitation of groundwater resources. To implement water withdrawal monitoring in major water users, such as waterworks, dyeing factories and power plants, is helpful to promote the coordinated of the social economy and ecological environment in the watershed even sustainable development.

With the popularization and application of advanced technology, such as computer technology, communication technology, the developed countries focus on the establishment of water resources monitoring system as a key project [3]. Paper [4] presents a model to disaggregate the water balance components of a monthly water resources system model to daily time series, which provides a pragmatic, but useful approach to disaggregating monthly water balance simulations for use within a daily water quality model. Paper [5] introduces some countries establish the optimal allocation and monitoring management system for large-scale irrigation area. With the combination of geographic information technology, communication technology and computer technology, they developed a visual monitoring system based on graph. Paper [6] presents a water quality monitoring system using a WSN to measure and monitor the water quality variations in the river areas. Paper [7] combines the WSN technologies and GPRS communication to set up a complete online water monitoring system.

Aiming at the quantity monitoring of water withdrawal, the general approach is to install a probe of a flowmeter for measuring water flow in a pipe, and display the real-time water flow from onsite flowmeter. In recent years, although China has made rapid progress in the field of water withdrawal monitoring, there are still some shortcomings. Monitoring system of each area is independent, so that there is no uniform interface standard, and supervision department cannot achieve unified management. Terminal devices run unstable, especially in some rural areas for the influence of lightning strike. Moreover, image acquisition is not considered in remote monitoring systems at the beginning of the design.

Along with the country's attention to usage quantity of water withdrawal the monitoring of water withdrawal is developing towards the direction of network and information. This paper takes the remote monitoring terminal that is the core part of the remote monitoring system as the research object so as to improve the accuracy and reliability of the monitoring system. Meanwhile, in view of the existing water monitoring system, we expand the related functions, such as remote software upgrade function and picture collecting function. This paper starts with the current application of the water resource monitoring technology and its shortcomings. Then in section 2, water withdrawal monitoring system is introduced, as well as the detailed hardware design of remote monitoring terminal. In section 3, System functions and software design are introduced. In section 4, some tests are conduct, and operating applications are provided. Section 5 is the conclusion.

II. HARDWARE DESIGN OF REMOTE MONITORING SYSTEM

The structure of the water withdrawal automatic monitoring system includes two parts, one is the water quantity collection system and the other is the monitoring center system [8]. In this part, we give a brief introduction to the overall design of this system, and focus on the detail hardware design of remote monitoring terminal that is the core of water quantity collection system.

A. *Structure of water withdrawal monitoring system*

According to the construction requirements of the project, large-scale water users whose water consumption is up to 3 million ton per year should be regulated by government supervision. Through inspection, the actual situation on site are summarized and analyzed. Intake water is stored or used directly from surface water sources through the water diversion pipeline. Water flow sensor is installed in the appropriate position of the pipeline. Nearby, corresponding flowmeter reads the signal of sensor and covert it to standard electric signal. Finally, the signal is processed by controller and displayed on computer in central control room. Fig. 1 provides the schematic diagram of field devices.

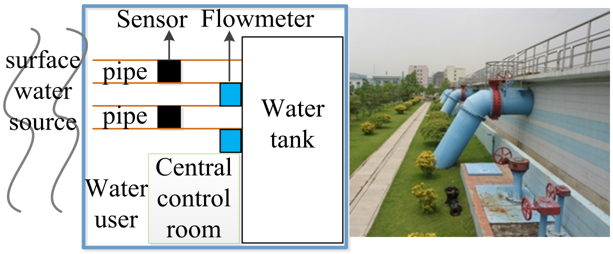

Figure 1. Equipment layout diagram of water user

Existing water withdrawal monitoring system just realizes on-site monitoring of water quantity, which cannot satisfy the requirement of remote monitoring and centralized management. Aiming at this situation, we design the remote monitoring system based on GPRS to realize on-site collection and remote monitoring.

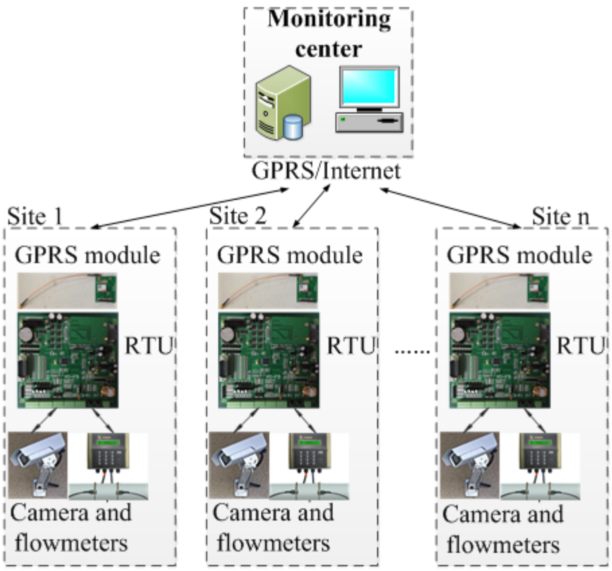

Figure 2. Water withdrawal monitoring framework base on GPRS

Remote data collection terminal contains the sensors, embedded processor, GPRS communication module, for the completion of environmental data collection, processing and transmission [9]. In this paper, we design the remote terminal unit (RTU) to transmit sensors' data through GPRS communication. The real-time monitoring server consists of a PC installed with software of data control. The PC has a fixed IP internet connection. The real-time monitoring server is used to control the system, data storage, data analysis and communication [8]. The water monitoring framework base on GPRS is designed as shown in Fig. 2.

RTU acts as on-filed data collection device. It finishes signal acquisition and data processing from the flowmeters and camera through RS485 bus. The GPRS module equipped with a SIM card is used to establish the internet connection. The central monitoring station include sending commands to RTUs, accepting the monitoring data from the RTUs, store and deal with database, and print historical data. It has a good man-machine interface.

B. *Hardware design of RTU*

RTU is designed according to principles of reliability, economy, practicability and expansibility. Major hardware of RTU includes main controller unit (MCU), its peripheral circuits, GPRS wireless communications module, and serial ports lines between them. Fig. 3 shows the hardware block diagram of RTU. The hardware circuit consists of power module, input circuit apartment, external memory, display module, key control module, wireless communication module, serial communication module.

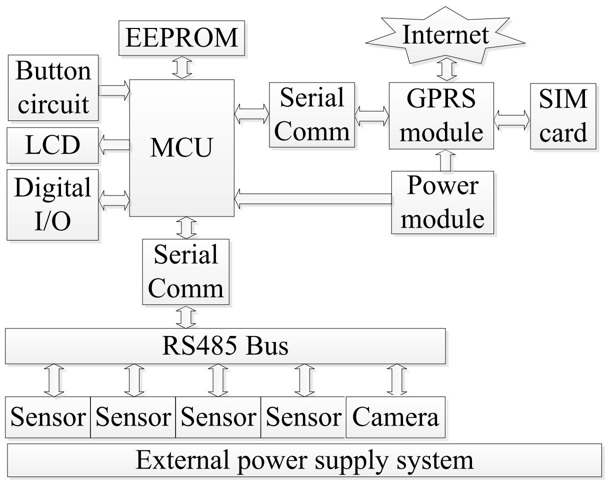

Figure 3. Hardware block diagram of RTU

1) *Main controller circuit design*

Based on the low power consumption and control performance requirements, PIC18F67K22 microcontroller is selected as MCU that is the core of the main control board. PIC18F87K22 is a kind of PIC18 set. This family combines the traditional advantages of all PIC18 microcontrollers – namely, high computational performance and a rich feature set – with an extremely competitive price point. These features make the PIC18F87K22 family a logical choice for many high-performance applications where price is a primary consideration [10]. In our design, two serial ports of MCU, UART1 and UART2, are respectively used to establish communication with GPRS module and sensors.

2) *Data storage circuit design*

According to paper [11], RTU need to have data storage capacity, and the data retention capacity is not less than 5 days. In our design, the stored data includes recent 5 days' sensor data, relevant parameters and upgrade program. Considering the limitation of storage capacity of microcontroller, we choose memory chip 24LC512 to extend the data storage circuit. According to paper [12], the Microchip Technology Inc. 24LC512 device is 512 Kbit Electrically Erased PROM. The device is organized in blocks of 8-bit memory with 2-wire serial interfaces. Parts having functional address lines allow connection of up to eight devices on the same bus. Endurance is up to 1000000 cycles. In our design, SDA pin and SCL pin of 24LC512 are respectively connected with Master Synchronous Serial Port (MSSP) module in I2C mode of PIC18F87K22. In I2C mode, SDA bus is used to transfer addresses and data into and out of 24LC512, and SCL bus is used to synchronize the data transfer to and from the device.

3) GPRS module circuit design

GPRS is a digital mobile communication network that develops rapidly in recent years. Wide network coverage of GPRS net makes it suitable for some water users in rural areas where there exist wireless signal coverage problems. The GPRS module is responsible for the communication and data transfer functions between the monitoring center and RTU. According to paper [13], the core chip of the GPRS module is SIM800C that is a quad-band GSM/GPRS module. This module works on frequencies 850MHz, 900MHz, 1800MHz and 1900MHz. SIM800C. It is a SMT package with 42 pads, and provides all hardware interfaces between the module and customers' boards. In our design, major hardware of GPRS module includes SIM800C and its peripheral circuits. We establish connection between TXD and RXD of GPRS module and UART1 of PIC18F87K22. Through the serial port, MCU send AT commands to control the GPRS module to complete the data transfer function.

4) RS485 interface circuit design

The paper has studied and realized the communication between RTU and multi-sensors. All sensors and camera linked to RTU through RS485 industrial control bus. RS485 interface is based on differential signal negative logic, which enhanced its ability of resistance to common mode interference. In our design, we use serial interface chip MAX485 to realize communication between master station and slave station. At a certain moment, there is only one kind of communication, namely receiving or sending.

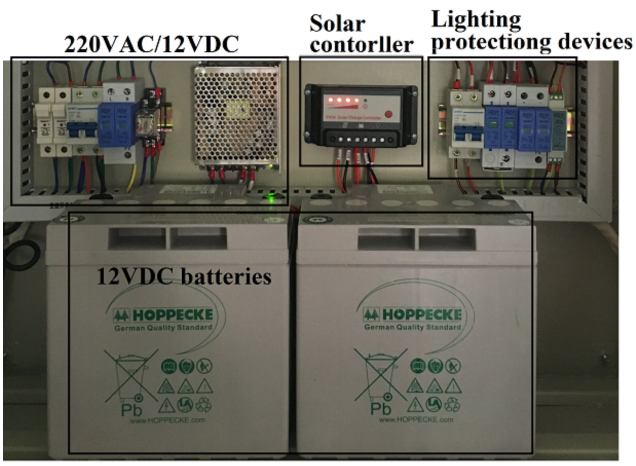

Figure 4. External power supply devices

C. External power supply design

RTU, flowmeters and camera in the monitoring terminal box are powered by a double power supply, switching power supply and battery. In power failure of switching power supply, the battery will offer the power. Solar cell and solar controller work together and convert solar energy to stable 12VDC, and then charge for battery. In most monitoring areas, monitoring terminal box is easily impact by lightning strike. The reasons why the instruments outside and inside monitoring terminal box are struck by lightning are analyzed. The reform of lightning protection is conducted with lightning protection devices for power supply and signal. Fig. 4 shows the external power supply devices in terminal box.

III. SOFTWARE DESIGN OF RTU

Data flow of the system is shown in Fig. 5. Data of flowmeter and camera is collected and processed through RS485 bus by RTU. After processed and stored, the data is sent to GPRS module, and sent to the monitor center through Internet.

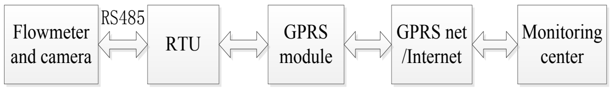

Figure 5. System data processing flow

A. Functions of RTU

The functions of application software are mainly divided into 6 modules, such as initialization, timer interruption, GPRS data transmission, water quantity collection, image transmission and remote upgrade module.

The initialization module mainly accomplishes initialization of each module. Meanwhile, initialization module reads the initial set value from the external storage EEPROM, and then sets the initial parameters of the system.

According to actual requirement, RTU needs to collect and self-report data periodically. Timer interruption module provides correct clock information for each module in system to enhance the transmission quality and efficiency.

B. GPRS data transmission

In our design, data transfer format is based on paper [11] that sets transmission protocols format standards for data transmission between central station and remote station. This uniform standard helps achieve monitoring management across different areas and disparate systems. RTU is configured with IP addresses and port numbers of monitoring station, and starts TCP connection with monitoring station through GPRS module. After TCP connection is conformed, information can be transformed to device at the other end through TCP link. By this, the system completes data exchange between RTU and monitoring center. The process of establishing a link between the GPRS module and monitoring station in the Internet is shown in Fig. 6.

In order to maintain the smooth flow of links, in the design of GPRS data transmission unit, we design a heartbeat packet that is issued every minute. Heartbeat packet is also regarded as one message.

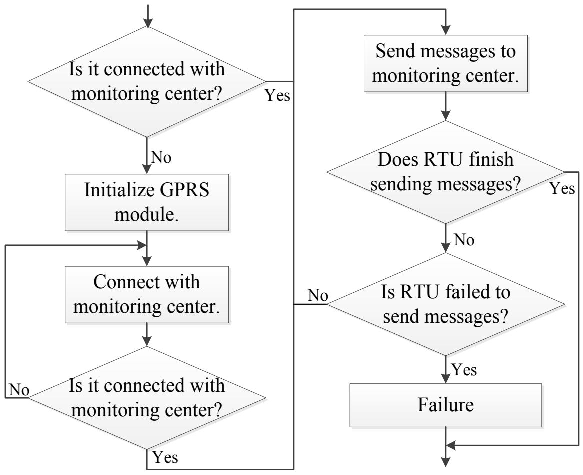

Figure 6. Progress of GPRS connection

C. *Water quantity collection*

The communication between RTU and flowmeters uses Modbus communication protocol and implements information exchange through the serial communication interface. In our design, considering that multi-flowmeters situation exists in most monitoring sites, we utilize interacting with interface provided on liquid crystal display (LCD) to setup communication parameters, so that RTU can switch different communication protocols and message forms according to practical use. The timer generates timing interrupt every one minute, and RTU start polling for each flowmeter's flow quantity. The process is shown in Fig. 7.

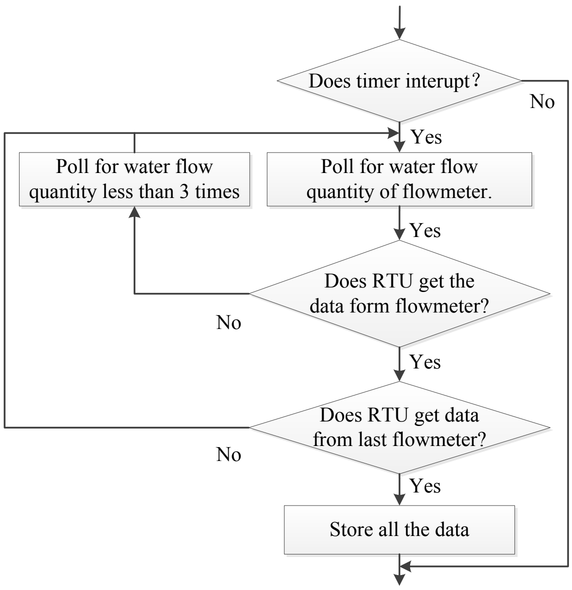

Figure 7. Progress of water quantity collection

In order to guarantee the reliability of RS-485 bus communication, each flowmeter receives 3 commands from RTU in case of communication abnormity. RTU also receives 3 returned messages, and then carries out simple data processing and store the processed value of water quantity.

D. *Image transmission*

Cameras are used in this project to capture images of field equipment. Some monitoring sites are selected in the wild or rural area where nobody guards. Through uploaded images, administrator can know whether the equipment is stolen, damaged or tampered artificially.

Because the data of the image document is relatively large, so it is necessary to make the sub-data in order to transmit in the GPRS network. In our design, RTU reads and sends image data by a fixed size packet, and monitoring center receives all the data and then package the data. When receives the picturing command from monitoring century, RTU sends cache cleaning instruction to the camera firstly. Then RTU sends picturing command and read the image length. According to the length, RTU calculates how many packages the picture is divided. Lastly, according to the transmission protocol, each frame of image data forms a packet, and is sent to monitoring center through GPRS module. Image transfer process is shown in Fig. 8.

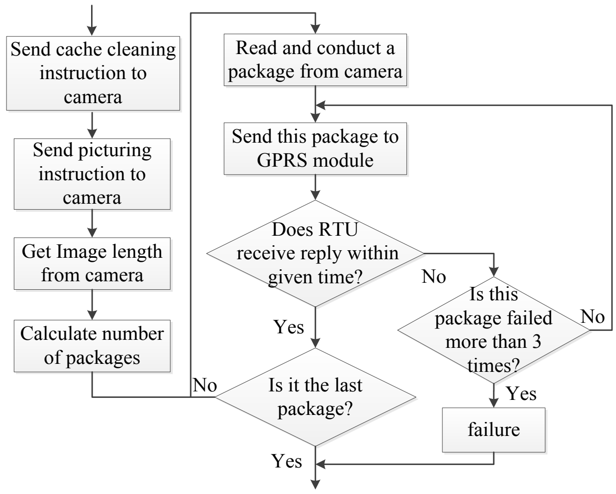

Figure 8. Progress of picture collection

E. *Remote upgrade*

Program upgrade in the field is unrealistic, for monitoring sites are broadly distributed. The purpose of remote upgrade is to upgrade the application program of RTU without people go to the scene, but directly through the monitoring center by the user, what makes remote online upgrade economy and efficient. Remote upgrade can be summarized as two parts: receiving application program and loading application program. The steps of receiving application program are as follows:

(1) Convert new application program into a binary file.

(2) Divide binary file and send divided data forwarded to the RTU through wireless network.

(3) RTU stores the verified code in extended EEPROM and set upgrade flag.

(4) RTU saves the relevant parameters and restarts program.

Fig. 9 shows the process of receiving application program.

After program is restarted, RTU will determine whether get into loading application program process according to upgrade flag. If the flag is set, program will run the second part of upgrade process. Otherwise, system directly jumps to application area to execute original application program. Fig. 10 shows the process of loading application program.

The upgrade process is irreversible. Therefore, each byte data is checked in both process of receiving application program and loading application program.

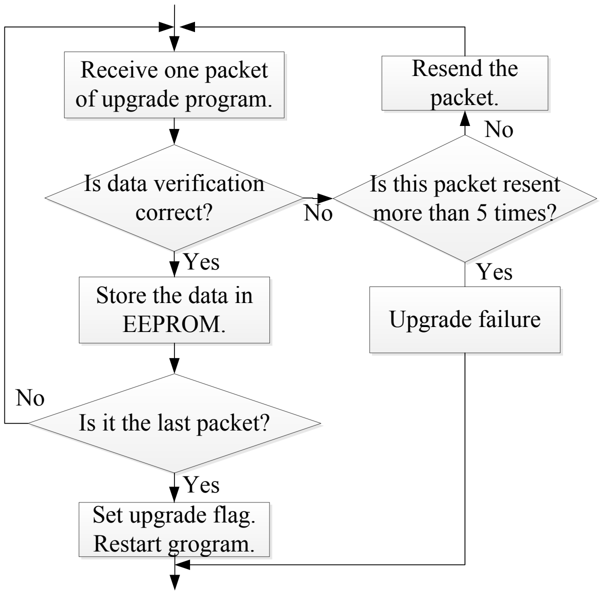

Figure 9. Progress of binary file receiving

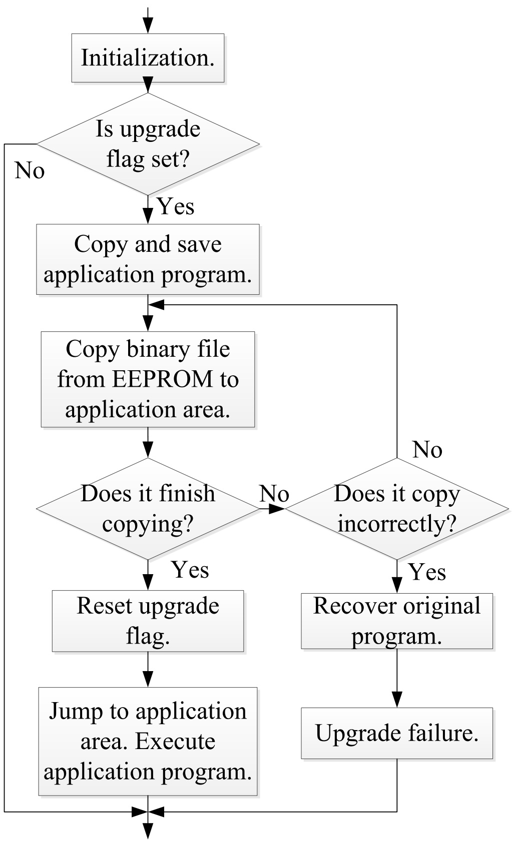

Figure 10. Copy progress of loading application program

IV. OPERATION IN WATER WITHDRAW MONITORING

So far, there are about 400 terminal boxes installed, and most of them operate normally. Here we give some test results of most commonly used functions.

A. *Instrument installation*

The sensor of flowmeter should be installed simply and conveniently, so as to reduce the installation cost and power depreciation. In addition, selected installing position should comply with certain regulations in order to reduce the measurement error. The solar energy plate should be installed in a suitable angle, so as to improve generating efficiency. The installation of relevant devices is shown in Fig. 11. Operating parameters of RTU and flowmeter reflect working condition of field devices. In our design, accumulative flow is the monitoring object. By checking accumulative flow of RTU and flowmeter, we can ensure the stability of the underlying data transmission.

B. *Test of water quantity collection*

RTU reports collected data to monitoring center through GPRS module at 15-minute intervals. In order to show the change curve of water flow, the monitor software provides a graphical display of each remote monitoring site. Fig. 12 shows the statistical chart of one monitoring site after running a period of time.

From Fig. 12 we can know that monitoring center update water flow data every 15 minutes. When system runs normally, the collected data of water flow varies in accordance with a smooth and increasing curve.

C. *Test of image collection*

In the monitoring center, administrator chooses site address of one monitoring site to get the scene image. RTU will display the progress of the transfer as shown in Fig. 13. After all packages are transmitted successfully, system can automatically assemble the packages. Fig. 14 shows the collected picture of one site.

Figure 11. Instrument installation in the field

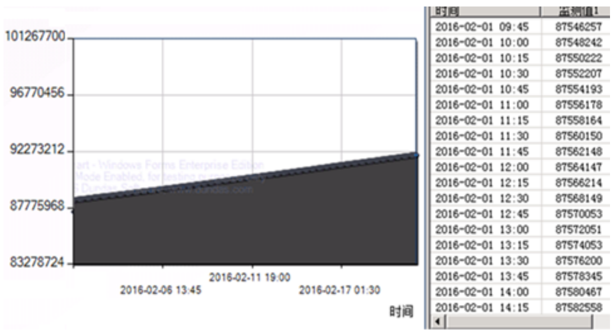

Figure 12. Statistical chart of one monitoring site

Figure 13. Display of RTU

Figure 14. Collected picture of one site

D. Test of remote upgrade

In monitoring center, administrator chooses remote monitoring site to be upgraded, and upload the binary file. After the start, monitoring center displays remote upgrade progress as shown in Fig. 15. In first step, RTU works normally and receive the packages of binary file. This progress can be reflected in LCD screen as shown in Fig. 16. In second step, RTU will restart automatically.

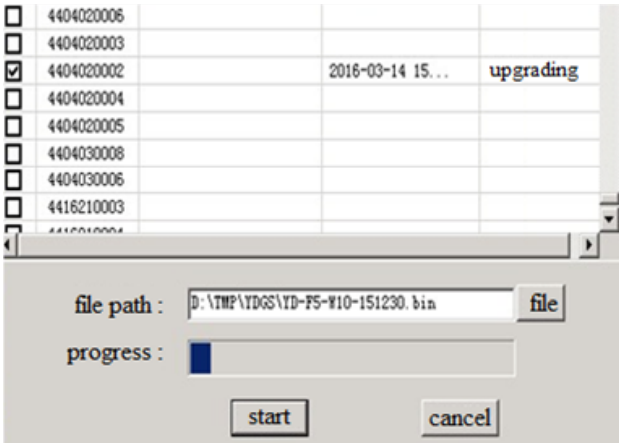

Figure 15. Display of monitoring center

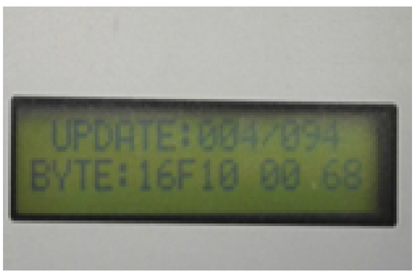

Figure 16. Display of RTU

In order to verify the reliability and stability of remote upgrade, three kinds of cases are simulated to test the function of remote upgrade.

(1) Cut off the power of RTU, when RTU is receiving application program.

(2) Disconnect network link between RTU and monitoring center when RTU is receiving application program.

(3)Cut off the power when RTU is loading application program.

According to our tests, although cases (1) and (2) led to failure of upgrading, RTU executes original program after external conditions return to normal. In case (3), when provided power supply, RTU continues loading application program, and finally complete progress of upgrading.

V. CONCLUSION

A remote monitoring terminal based on GPRS mode with high reliability and complete function is designed. Remote monitoring station can be able to send the collected data dealt with by RTU to central monitoring station. RTU can also receive the setting command from the central monitoring station and complete various tasks. At the same time, through the rational cooperation of software and hardware, RTU can adapt to different types of sensor units. Remote upgrade function is proposed in order to have a convenient maintenance. Upon completion of the basic functional, this paper adopts image transmission based on GPRS to realize the monitoring of field instruments. This set of monitoring terminal system has been installed and operated for some time in a south province in China. Still now, about 400 users of water withdrawal have been brought into the regulatory, and the data of water quantity can be obtained in monitoring center stably, as well as other data.

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