BeiDou-based borehole hydrological intelligent monitoring system design

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Abstract. An intelligent monitoring system for borehole hydrology based on Beidou is designed. This system uses input sensors to measure water level and water temperature in boreholes. The intelligent terminal uses the STM32F103RCT6 microprocessor as its core, and adopts a timed power-on mode of operation to collect water level and water temperature information, uploads the collected water level and water temperature data to the gateway through the Beidou module, and uploads the water level and water temperature data to the OneNET platform through the GSM network via the gateway, the OneNET platform provides intelligent statistical analysis of uploaded data, enabling real-time monitoring and early warning of water levels and temperatures in boreholes, effectively preventing and controlling water damage in mines.

1. Introduction

As an important energy source in our country, the demand for coal is increasing with the acceleration of modernization, and the coal industry is developing rapidly[1][2]. However, the problem of coal mine disasters is becoming increasingly serious[3]. As one of the five major natural disasters in coal mines, water disasters have caused serious loss of life and property. With the increasing complexity of the mine geological environment, the potential water hazards also increase. In the process of coal mining, water disasters are extremely dangerous to the safe production of coal mines. Therefore, it is of great significance to know the underground hydrological conditions of coal mines intelligently to prevent and control water disasters in coal mines, and it is also one of the keys to realizing smart mines and safe mines.

For foreign countries, in recent years, the latest generation of hydrological telemetry systems in the United States has been successfully developed with the approval of the National Oceanic and Atmospheric Administration of the United States. In the transport layer, satellite transmission means and the American sea level, and a large watershed measurement network are used to centrally process the data collected by sensors. For domestic, widely used hydrological telemetry systems mostly use manual input pressure sensors to measure water level buried depth data, and wirelessly transmit data in the form of short messages via GSM network[4][5]. At present, the wireless communication mode of the hydrological telemetry system has gradually evolved into 4G, WiFi, ZigBee, and NB-IoT. Although wireless communication technology has made great progress in recent years, the borehole monitoring points in some mountainous areas and remote areas are still in areas beyond the coverage of network signals. To solve this problem, an intelligent borehole hydrological monitoring system based on Beidou is designed.
2. System structure and working principle

2.1. System structure
The overall structure of the monitoring system is shown in Figure 1, including three parts: smart terminal, data transmission, and monitoring centre. The intelligent terminal comprises an input water level and temperature sensor, an anti-stretch communication cable, a pulley, an intelligent telemeter, a rechargeable lithium battery, and a solar panel. The data transmission part includes the Beidou satellite, gateway, GSM network, and OneNET platform. The monitoring centre includes a monitoring server and a mobile phone.

![System structure diagram](image)

2.2. System working principles
The specific working principle of the system is as follows: the intelligent terminal of the system supplies power through the rechargeable lithium battery and adopts the timing power-on mode to collect data. When the timing is up, the microprocessor STM32F103RCT6 inside the smart telemeter turns on the working mode to control the water level and temperature sensor for measurement. The data measured by the water level and temperature sensor is transmitted to the microprocessor inside the intelligent telemeter by RS485 bus, and then the microprocessor drives the Beidou module to encrypt the communication application signal containing the receiver ID number and measurement data and then forward it to the station via satellite. After receiving the communication application signal, the ground central station will be added to the outbound broadcast message which is continuously broadcast after decryption and re-encryption, which will be broadcast to the Beidou
module in the gateway via satellite, and then the data will be uploaded to OneNET platform via GSM network after communication protocol conversion.

The principle of the system terminal to obtain the real-time water level of the borehole is as follows: the water level sensor can measure the real-time depth of the sensor below the water surface, i.e. the sensor reading, and record the depth of the sensor lowered during installation, i.e. the sensor burial depth. The real-time water level of the borehole is the difference between the sensor burial depth and the sensor reading, and the real-time water level of the borehole can be calculated by the microprocessor inside the water level sensor.

2.3. Intelligent Telemetry
The intelligent telemeter includes the Beidou module, Bluetooth module, microprocessor, step-down circuit, and power management circuit. The smart telemeter is powered by an external 12V lithium battery, and powers each module after stepping down through a step-down circuit. The internal structure diagram of the intelligent telemeter is shown in Figure 2.

Figure 2. Hardware logic structure of the intelligent telemetry.

Figure 3. Bluetooth module interface circuit.
2.3.1. Bluetooth module. In this system, the Bluetooth module mainly completes the communication between the mobile phone and the intelligent telemeter, so that the mobile phone APP can set the
parameters of the terminal equipment and display the measured data. ATK-HC05 module can be directly driven by a microprocessor under 5V voltage, and then supplied with power through 12V to 5V buck circuit. The microprocessor is connected with ATK-HC05 through USART3. The interface circuit design of the ATK-HC05 is shown in Figure 3.

2.3.2. Beidou module. Beidou module uses TM8510 module, which integrates RDSS RF transceiver chip, power amplifier chip, baseband circuit, etc., and can fully realize all functions of RDSS transceiver signal and modulation and demodulation [6]. Because the serial communication interface of the TM8510 module and the serial communication interface of the microprocessor STM32 in the intelligent telemeter are at 3.3V TTL level, the 18-pin RX_BD and the 20-pin TX_BD of the TM8510 module can be connected to the USART1 of the microprocessor for communication, and the power supply voltage is 5V, which can be supplied after being stepped down by the 12V to 5V step-down circuit. The interface circuit design between the Beidou module and microprocessor is shown in Figure 4.

2.3.3. Power control circuit. In order to ensure the low power consumption of the system, it is necessary that the intelligent terminal can be powered on regularly, so it is necessary to design a power control circuit, which can make the clock chip control the switch chip IRF7424. In this system, the collector of transistor 9014 is connected to the G pin of IRF7424. When the IRQ pin and key of the clock chip generate a low level, IRF7424 turns on the device to power up. At this time, the base of 9014 is extremely high, ensuring that 9014 is continuously turned on. After the data acquisition and uploading work is completed, the MCU generates a low level to pull down the base of 9014 through a pin before entering sleep, and 9014 is not conducting. The G pin of IRF7424 becomes high level, IRF7424 is turned off, and other parts of the terminal equipment are powered off, thus entering a low-power sleep state. The power control circuit diagram is shown in Figure 5.

2.4. Water level and Water temperature sensor

The water level and temperature sensor circuits of this system are mainly composed of silicon piezoresistive water level sensors, water temperature sensors, a signal amplification circuit, a microprocessor, and communication interface circuits. The silicon piezoresistive water level sensor is essentially a differential pressure sensor. The back of the water level sensor is communicated with the atmosphere by using an air conducting communication cable so that the pressure on the back of the water level sensor is always atmospheric. The pressure difference between the front and back of the sensor will result in analogue differential electrical signals. The signal amplification circuit amplifies and filters the generated analogue signals, then converts the analogue signals into digital information by using AD conversion chip AD7705, and calculates the buried depth of drilling water level through the internal formula of the microprocessor. The water temperature sensor uses DS18B20 single-line digital temperature sensor, and the power supply voltage is 3.3V. The sensor communicates with the I/O port of the single-chip microcomputer in a single-bus interface way, saving the resources of the I/O port. The communication pin of DS18B20 can be directly connected with the PA4 pin of the single-chip microcomputer for water temperature data transmission. The water temperature sensor can measure the water temperature and compensate for the measurement of the water level sensor. Because the water level and temperature sensor transmit data to the intelligent telemeter through the RS485 bus, RS485 communication interfaces are designed inside both sensors, and data transmission can be carried out after direct connection.

2.5. Gateway

As the Beidou module cannot directly transmit data with the OneNET platform, it is necessary to add a gateway in the data transmission part, which is connected with the OneNET platform through the GSM module for data transmission. The gateway contains the TM8510 module, SIM800C module, microprocessor STM32F103RCT6, and some peripheral circuits. The gateway uses AC220V to
DC12V module for DC power supply, the network management internally designs a 12V to 3.3V step-down circuit to power the microcontroller, a 12V to 5V step-down circuit to power the TM8510 module and SIM800C module, the step-down circuit in the gateway, and the smart telemeter. The step-down circuit is the same. Because the serial communication interfaces of the microprocessor and the two modules are both 3.3V TTL level, they can communicate through the serial connection. The TM8510 interface is connected to USART1, and the SIM800C interface is connected to USART3. The hardware logic structure of the gateway is shown in Figure 6.

![Figure 6. Hardware logic diagram of the gateway.](image)

### 3. Monitoring system software design

![Figure 7. Flow chart of the main program of the intelligent telemetry.](image)

![Figure 8. Flow chart of the main gateway program.](image)
3.1. Intelligent terminal data acquisition software

The main program flow chart of the intelligent telemeter of the monitoring system is shown in Figure 7.

The system collects borehole hydrological data based on microprocessor STM32F103RCT6. Firstly, the system is initialized, which includes real-time time initialization, data measurement, and transmission time initialization, and configuration of GPIO pins and serial port working modes corresponding to USART serial ports. Then, self-check the Beidou module, and continue to execute the program if the self-check is normal. If the self-check is abnormal three times, it will automatically power off; after reaching the timing time, the microprocessor collects the sensor measurement information. Because the collected information follows Modbus protocol, the microprocessor needs to decode the collected information and convert it into the format following RDSS2.1 protocol, and then drive the Beidou module to send data to the gateway.

3.2. Gateway data transmission software design

The flow diagram of the main gateway program is shown in Figure 8.

After the gateway is powered on, the system is initialized. The initialization content includes timer initialization, the configuration of the corresponding GPIO pins and serial port working mode of the USART serial port, and then self-checking the Beidou module and the GSM module. If the self-checking is normal, the gateway opens the working mode. And the working mode is always on in the power supply state. After the gateway receives the data, the microprocessor decodes the Beidou short message received by the Beidou module, and converts it into content conforming to the MQTT protocol format, and sends it through the GSM module. The program for connecting the GSM module to the OneNET platform is burned into the microprocessor in the gateway, and the gateway is connected to the OneNET platform through the AT command for data transmission.

4. System test

Connect the smart terminal hardware devices, power the gateway, and keep it on. Follow the steps to add devices on the OneNET platform to connect the gateway to the OneNET platform. When the smart terminal reaches the measurement time, power on and upload the sensor data to the OneNET platform. The OneNET platform test results are shown in Figure 9. After exporting the data from the OneNET platform, the historical curve is generated as shown in Figure 10.

![Figure 9. OneNET platform test results.](image1.png)
![Figure 10. Water level and temperature history curve.](image2.png)

It can be seen from the test results that the intelligent terminal can control the sensors to collect data, transmit the data to the gateway through the Beidou module, and finally successfully transmit the data to the OneNET platform through the gateway.
5. Conclusion
In this paper, a drilling hydrological intelligent monitoring system based on Beidou is designed. The intelligent terminal of this system adopts regular power-on to collect hydrological information, which realizes low power consumption and meets the requirements of long-time work of field intelligent terminals. It is proposed to increase the gateway from Beidou short message communication to GSM network communication, so as to access OneNET platform for intelligent statistical analysis of monitoring data, realize the combination of sensor and Internet of Things technology, and solve the problem that borehole hydrological measurement data cannot be uploaded in areas where network signals are not covered or signals are weak. Workers can log in to the OneNET platform through mobile phones and computers to view real-time data anytime and anywhere, and when the hydrological data reaches the early warning value, the OneNET platform will send an early warning email to the preset mailbox to more comprehensively ensure the safe production of coal mines.

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