Design of Roof Abscission Layer Wireless Monitoring System Based on 433MHz RF Technology

Junwu Yao, Hongxian Tian
College of Electronical and Information Engineering,Beijing Jiaotong University,Beijing, China
College of Electronical and Information Engineering,Beijing Jiaotong University,Beijing, China
junwu6311@126.con, hxtian@bjtu.edu.cn

ABSTRACT

In order to improve the safety of coal mine production further, the paper designs a roof abscission layer wireless monitoring system based on 433MHz RF technology. Monitoring sub-stations and nodes under the ground form a distributed wireless network and communicate with each other via wireless data transmission module CC1100. In this wireless network, sub-stations, connecting to remote monitoring center via underground fiber optic ring network, are the network gateway, which are responsible for managing nodes near the sub-station and collecting monitoring data. Nodes, using the displacement sensor to monitor the roof separation displacement information, adopt MSP430 chip as the microprocessor and have the characteristic of low power, auto sleep function and several ways to wake up. The system we designed is benefit for using radio frequency technology to communicate under the mine. It can not only monitor the roof separation displacement information real-time and send the warning message timely, but also reduce the cost of installation and maintenance.

Keywords-433M RF Technology; Real-time Monitoring; Low-power Consumption; Roof Separation; Displacement Information

1. INTRODUCTION

With the increasing intensity of coal mining and the trend to deep mining, roof safety issues have aroused a great concern. Roof separation is the rapid emergence of stair jumping when the rocks of roadway between the surrounding and away from the surrounding become deformed. When the roof abscission layer above a certain range, that is, when the roof is in an unstable state, it will fall with malignant roof accident if a prompt supporting measure isn't taken. Therefore, real-time monitoring of roof separation of information plays a very important role. Currently, roof separation systems are mainly measured by people regularly observing the roof abscission layer situation and the cable type to connect multiple sensors. The former one has a larger prison monitoring error and is poor in real-time performance. The latter one is short for network cabling, and has high installation and maintenance costs. Therefore, the paper designs a new automated monitoring and alarm system. The system, which is based on 433MHz RF technology, uses wireless sensor networks to communicate the information of roof separation. It achieves timely and accurately prediction of the accident, as well as realizing easy system maintenance, network expansion and recovery ability

2.SYSTEM OVERVIEW

Roof abscission layer wireless monitoring system is a specialized automatically monitoring and early warning system for the roof separation displacement in the mine roadway [2]. It mainly consists of four parts: monitoring sub-stations, nodes, portable data collectors and remote monitoring center. Monitoring sub-stations collect node's information regularly via 433MHz wireless network and transmit to the remote monitoring center via underground Ethernet network. Node which possesses displacement sensor and wireless communication module is installed in the top of the roadway, responsible for detecting roof separation data and reporting it to monitoring sub-station. Portable data collector collects the information of special node or monitoring sub-station through 433MHz wireless network and importes the information to the remote monitoring center via USB port. Remote monitoring center is in charge of handling data, and display monitoring data by list or chart or other means, as result to realize the safety in production by remote monitoring. Roof abscission layer wireless monitoring system is shown in figure 1.

978-1-4799-2186-7/14/$31.00 ©2014 IEEE

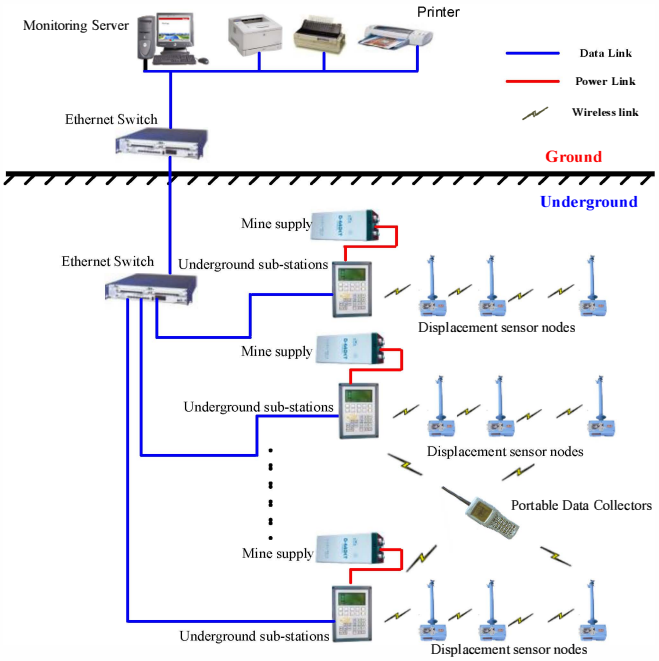

Figure 1. Structure diagram of roof abscission layer wireless monitoring system

3.HARDWARE DESIGN

3.1.Node Hardware Design

Node includes low-power microprocessor MSP430F5418, CC1100 wireless communication module, LCD module, battery module and displacement sensor. The hardware schematic diagram of node is shown in Figure 2.

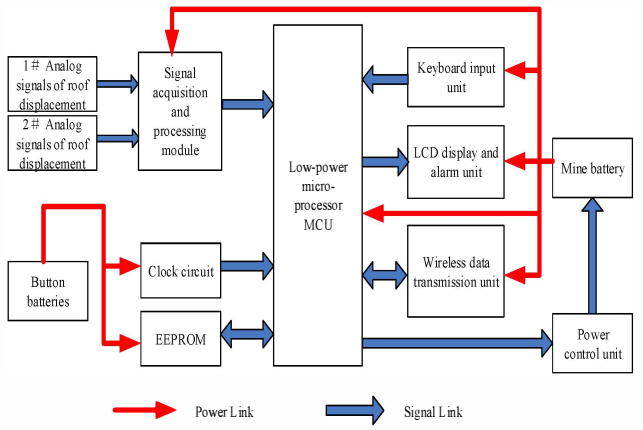

Figure 2. GUN500 node structure diagram

MCU, a low-power microprocessor module, is the core of node design[3]. This system uses the MSP430F5418 processor, which is a 16-bit ultra-low power mixed-signal processor. In addition, it has a lot of resources integrated in the chip. The MCU can process the data from displacement sensor and display in the LCD screen. What's more, it can give different instructions to LED and alarming sensor depending on different circumstances. The keyboard module is used to configure the ID, threshold and to clear the displacement zero during the install process. LCD module is able to display separation data real-time.

The core controller of the system is CC1100 which is a low-cost low-power UHF transceivers, The CC1100 is highly suited for systems where ultra low power consumption is required. This is ensured by various operating modes. Its main features are as shown below: High performance and low power ARM microcontroller core; Four types of sleep patterns; few transition times from low power pattern to active pattern ,ultra low average power consumption. The characteristic of CC1100 can make the battery using life longer, especially in the situation where is hard to perform maintenance on equipment in the pit. CC1100 communications connects MSP430F5418 through the SPI interface,which is a simple 4 wire SPI-compatible interface (pins SI, SO, SCLK and CSn). The schematic diagram can be shown in Figure 3.

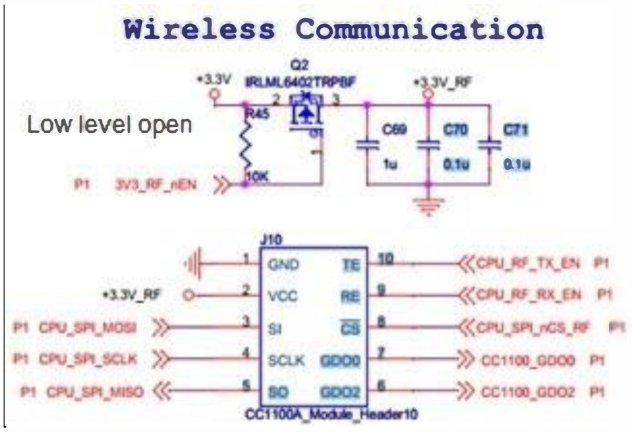

Figure 3. CC1100 schematics diagram

Two power supply modules include: button batteries and battery pack mine. Among them, the button battery EEPROM, real-time clock; mine is a low-power battery pack microprocessor, keyboard input unit, signal processing

and detection circuits, liquid crystal display and alarm unit, wireless data transmission unit power supply. Button battery can work continuously for more than two years, and mine battery can work continuously for more than 1 year.

3.2.Monitoring Sub-station

Monitoring Sub-station includes Low power consumption microprocessor MCU, wireless communication training module CC1100, communication network interface unit, LCD display, sound alarm unit, and the intrinsically safe circuit. The hardware schematic diagram of monitoring substation is shown in Figure 4.

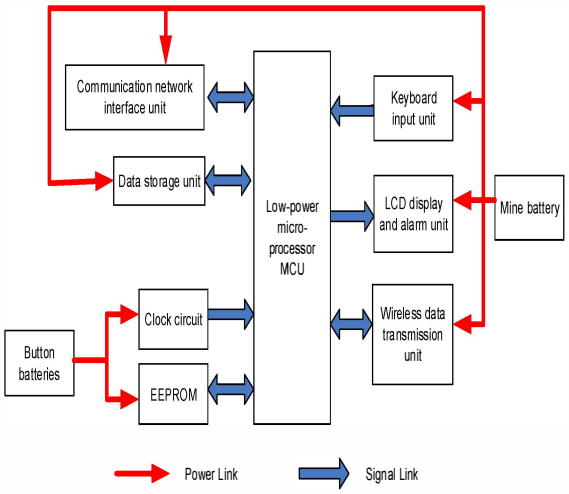

Figure 4. Structure diagram of intrinsically safe monitoring sub-station

Monitoring sub-station microprocessor MCU adopts LPC1768 SoC chipwhicth based on ARM Cortex-M3 with the characteristics of high integration and low power consumption, operating at 100MHz. LPC1768 chip's peripheral component contains 512KB flash memory , 64KB data storage unit, Ethernet MAC, 4 UART ports and an SPI interface.

LPC1758 microprocessor receives local roof monitoring data via wireless communication module CC1100 and stores to local flash storage. LPC1758 microprocessor transmits data to the remote monitoring center through underground fiber optic ring network[4].

4.SYSTEM SOFTWARE DESIGN

4.1.Node Software Design

Node can collect the displacement of the roof separation periodically and save them into local store. Meanwhile, the node is responsible to send the history data to the monitoring sub-stations when the monitor requests data. If a node detects the displacement exceeds its limits, it will send a warning to the monitoring sub-stations at once while the warning light will begin to blink before the node receive the alarm confirmation from monitoring sub-stations. It's very convenient for users to view the nodes' displacement through the LCD display or configure the threshold value by the keyboard. Figure 5 is the work flowchart of software in the node.

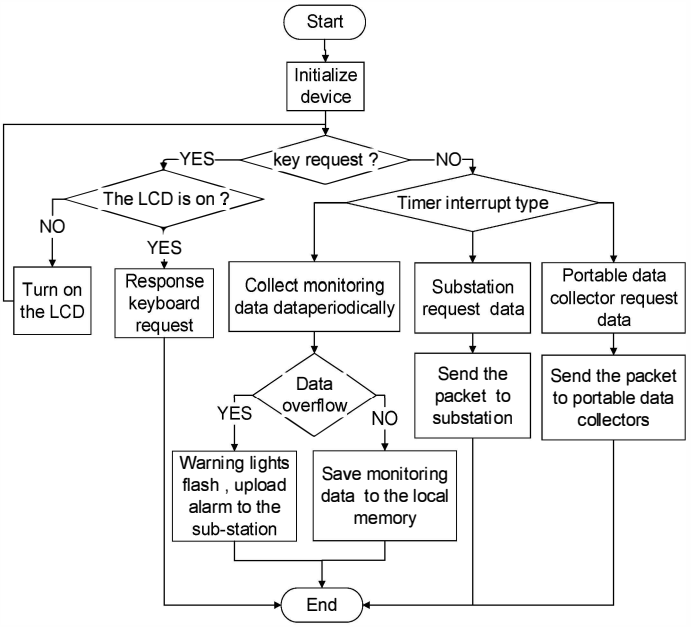

Figure 5 The flow chart of Node software

4.2Monitoring Sub-station software design

The monitoring sub-stations are responsible for collecting the data from the sensor node nearby, and send these information to the remote monitoring center when the center requests data. If a node sends alarm information, the monitoring sub-station will send an acknowledgment packet to the node to stop the indicator light flashing. Then monitoring sub-stations will send the warning information to the remote monitoring center to inform staffs that there will be safety risk under the mine. The

staffs also can adjust the monitored parameter or configure the transmission time interval of a special node or all nodes. The software work flowchart of monitoring sub-stations is depicted in Figure 6.

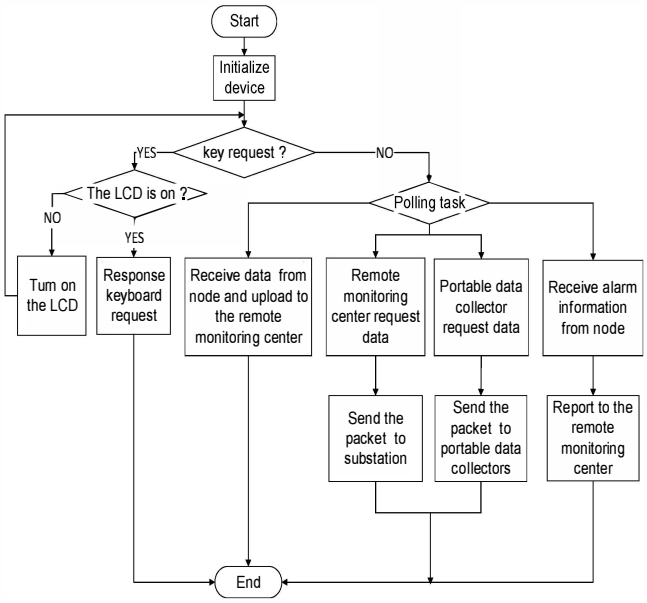

Figure 6. The flow chart of monitoring sub-station software

5. CONCLUSION

This systemhas obtained the national coal safety certification in May 2013, and the certification ID is KJ661. Now it has been applied in Jinding coal mine, Jincheng Blue Flame Coal Industry in October 2013 and run in good condition currently. The system parameters are shown in Table 1:

Table 1 System Specifications

Technical Parameters	Index
Roof separation displacement resolution	1 mm
Wireless communication frequency	433 MHz
Wireless transmission rate	240 Kbps
Wireless Transmit Power	0 dBm
Roof separation measurement range	0 ~ 500 mm
Wireless transmission distance	less than 100 m
Underground sub-station capacity	64 Nodes

REFERENCES

1 W.J.Ju,"Monitoring technology for rock bolting engineering," [J].Journal of China Coal Society, Vol . 25 , Sup, pp58-61, Dec 2000

2 W.J.Zhang, H.W.Zhang, and S.G.Yu, "Study on the monitor method of roof separation in bolter support roadway,"[J].Journal of Liaoning Technical University, Vol.21, No.4, pp.421-424, Aug 2002.

3 L.M.Xu, J.P.Jian, F.Q.Wang, and Y.L.Qu, "KZL-300 roadway roof separation Automatic monitoring and alarm systems" [J]. Shandong Coal Science and Technology, 2003 (2) :31-32

4 Y.Zhang, Y.W.Tan, H.L.Stormer, et al. "Experimental observation of the quantum Hall effect and Berry's phase in grapheme"[J]. Nature, 2005, 438(7065): 201-204.