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The Research and Design for the Controlling System of Coal Mine Rescue Capsule

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Abstract: The safety role of rescue capsule is paid more and more attention in coal mine. This article presents the principle and design of the rescue capsule controlling system. The controlling system includes the peripheral equipments, the power supplying devices and the monitoring circuit board. The board takes use of multi-microprocessor module to collect data, communicate each other, display information and control other device. The microprocessors communicate and exchange data between each other through I^2C bus. It is found that this design can fully meet the national requirements after experiments. *Copyright © 2013 IFSA.*

Keywords: Rescue capsule, Control, Microprocessor, Coal mine, Design.

1. Introduction

To effectively protect the lives and safety of coal miners and to promote exploiting mineral resources safely and orderly, South Africa, Canada, USA, Australia and other developed countries overseas have studied and applied the refuge chamber of coal mine, which is with the function of underground mine safety protection. There are already a number of successful rescue experiences. October 2010, 33 miners were trapped underground 624 meters depth in the San Jose mine in Chile. They were successfully rescued with the help of emergency refuge system after 69 days. On the other hand, the developed countries in mine safety have formulated strict laws, rules, and regulations for mine safety protection [1, 2].

At presents, lots of countries invest much energy to study and build mine refuge chambers or rescue capsules. In recent years, China learn from the advanced experience of other countries, put in a lot of manpower, funds in the field of coal mine safety protection work, and continue to establish and improve mine refuge chambers or rescue capsules.

The coal mine rescue capsule can withstand external explosion impact, high temperature gas, and can isolate coal miner from the toxic and harmful gases. They also can provide food, water, oxygen and win a long survival time for the trapped miners. At meantime, the trapped miners are able to guide the outside rescuers through the communication monitoring equipment. Therefore, the rescue capsule will become important escape equipment for coal miners [3, 4].

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The controlling system of mine rescue capsule is important part of it, including of the power supplying system, the environmental monitoring system, the controlling system and the communication system. This particle mainly presents the design of the refuge capsule's controlling system. The control system structure is shown in Fig. 1.

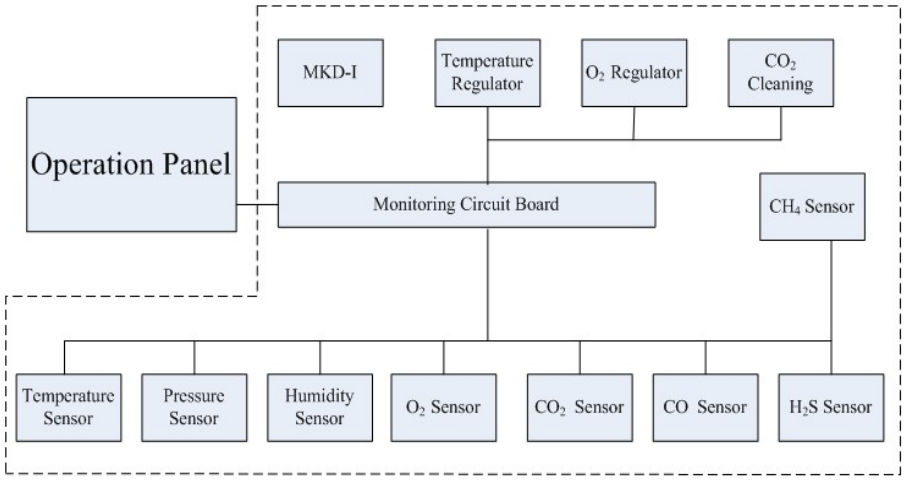

Fig. 1. The controlling system's structure.

2. The Peripheral Equipments in the Capsule

The peripheral equipments are executive body, which can carry out the instruction from the monitoring circuit board. They consist of the oxygen automatic adjusting device, the temperature automatic adjusting device, and the monitoring and treatment device for the harmful gas.

2.1. The Oxygen Automatic Adjusting Device

Oxygen is an important element for human surviving. In line with the national standards requirements, the oxygen concentration should be in the range of 18 % - 25 % in the rescue capsule. So, there must be some oxygen adjusting device. According to the oxygen concentration inside, the device can adjust the amount and speed of releasing oxygen. The controlling system sends switching signal to the oxygen solenoid valve to execute the adjusting function. Meanwhile, the manual adjusting oxygen device is alternate for oxygen when there is some unforeseen circumstance [5-6].

2.2. The Temperature Automatic Adjusting Device

Another condition for human survival is the air temperature. According to national standards requirements, the temperature inside the rescue capsule is in the range of 25 °C-35 °C. In the rescue capsule, a normal adult can release 10133.76 kJ calories per day. Also, the Chemical reaction of dealing with CO_2 and other harmful gases will release much heat. Because the rescue capsule is a closed adiabatic hull, this releasing heat will be accumulated in the hull constantly. And without timely treatment, it will lead to the rise of temperature in the capsule and the heat will do harm to the miners. So, there must be some temperature automatic adjusting device. By designing and installing an air-conditioning system which is appropriate for the rescue capsule, the temperature problem can be solved opportunely. In consideration that its build-in barratry is the only electric power, and the efficiency of the air-condition is depend on the time of the power supply, the most reasonable design is not only save power consumption but also assure air conditioning can run as long as needed. Only in this way the rescue capsule can protect personal safety up to the hilt.

There is a large-capacity tank in the rescue capsule. Enough water is in the tank. With compressor, the water is frozen into ice. When there is emergency, the heat air is driven by fans and flows through the ice. Then, the air temperature lowers.

2.3. The Monitoring and Treatment Device for the Harmful Gas

Usually, the trapped in the rescue capsule survive from a few hours to a few days. As time goes by, the rescue capsule will be filled with CO_2, CO, H_2S, CH_4 and other harmful gases exhausted by the trapped or coming from the outside of the rescue capsule. As time goes on, their concentrations are increasing, which would threaten people's life. Besides, the

trapped need to know about the whole capsule's working condition and take effective measures on an emergency like equipment failure. So the rescue capsule needs to be equipped with monitoring instruments to monitor harmful gas. The air concentration measuring instruments are the concentration sensors for mine specific. They can be bought from market.

Generally speaking, the density of O_2 in the rescue capsule is not less than 19.5 %, the density of CO_2 is less than 0.5 % and the density of CO is less than 10 PPM. So the pressure, temperature, humidity and so on must be real-time monitored and the alarm values can be set. The human body consumes O_2, as well as discharges of CO_2. The CO_2 cleaning equipment must run timely according to the monitoring result. Through the chemical reaction between soda lime and other adsorbents, the air becomes clean. So, there must be a fan to drive the air flowing. The fan is droved by the power supplying device and controlled by the monitoring circuit board.

3. The Power Supplying Devices

When the mine accident happens, mine power supply will be cut off. So the rescue capsule must depend on its own battery to provide the power, rather than external power supply. The battery is regarded as the heart of the rescue capsule. Only a table safety power supply can ensure the rescue capsule's lighting, communication and controlling function in the good operation, so as to ensure the safety of the people in the disaster period. Lithium iron phosphate battery pack is adopted as the supplying device, which can be bought in market. Its voltage is 24V. That is:

$$U = 24V \tag{1}$$

The consumption power P altogether in the capsule is 60 W. That is:

$$P = 60W \tag{2}$$

So, the load current is:

$$I = P/U = 2.50A \tag{3}$$

Then, the consumption capacity is:

$$M_1 = I \times T = 2.50 \times 96h = 240Ah \tag{4}$$

There, T is 96 hours according to the national requirements. The Safety factor K is 1.8. The Battery capacity M is:

$$M = M_1 \times K = 432Ah \tag{5}$$

In addition to the batteries, the power supplying devices includes the charger and other devices. The schematic of it is shown as Fig. 2.

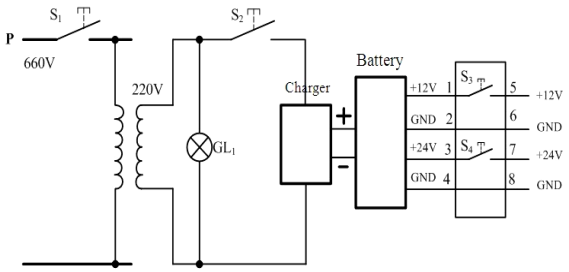

Fig. 2. The schematic of the power supplying.

4. The Monitoring Circuit Board

All life-support systems in the rescue capsule must be kept in normal operation constantly to make them stable and in the suitable range for human survival. In the rescue capsule controlling system, the monitoring circuit board takes the important task and it is the core of the controlling system. The board receives the signal from sensors, do the work of overrun judgment, logic operation and data processing, etc. Though sending an output controlling signal according to the calculation result and the controlling equipment action, the board can achieve the goals of controlling. The trapped miners can also manually operated devices through the operation panel if there are some unusual circumstances.

The monitoring circuit board mainly consists of the power supply circuit, the communication circuit, the input and output circuit, and the operation panel. The main board has RS485 communication port, 8-channel input circuit, 6-channel output circuit, digital display panel and so on. The digital display panel is mainly composed of LED and 74 HC595, a driving chip. By using three microprocessors, the board can realize communication, data acquisition, controlling, display function and make the output control time less than 2 s. The basic design idea is that the controlling MCU is responsible for communication and controlling; the data acquisition MCU and the data display MCU play the auxiliary role. The three microprocessors realize the communication task through I^2C bus. The internal structure of the monitoring circuit board is shown in Fig. 3.

4.1. The Power Supply Circuit

The circuit board's input voltage is 9 V ~ 24 V. The circuit design ensures the essential safety requirements. According to the anti-interference requirement and the power consumption, the design uses CS51414 (a step-down converter), the isolated DC - DC conversion technology. The switch frequency is up to 520 kHz. The power supply circuit

uses the smaller inductance and capacitance under the precondition of ensuring reliable power supply. The input terminal includes resettable fuse, which can limit the total power supply current. The input port accesses the diode, which can prevent users to pick the wrong power's electrodes and to burn the controller. At the same time, it can prevent the capacitor discharge effect of the controller for the power supply. So, the controller capacitance won't discharge to the power supply circuit and improve the power capacity.

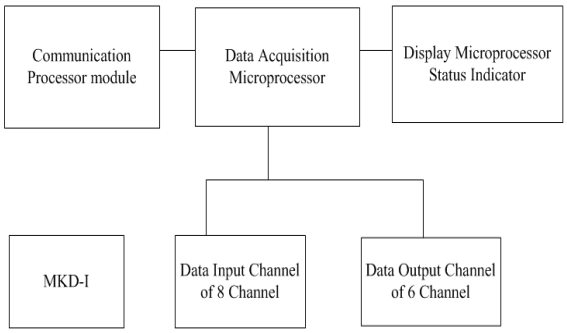

Fig. 3. The internal structure of the monitoring circuit board.

The power input inductance filters the high frequency interference, prevents the board interference to other lines. TVS (transient voltage suppressor) is connected to the DC - DC output end in parallel, which can limit input and output voltage, protect the controller and improve the security of the system.

4.2. The Communication Circuit

The monitoring circuit board has a RS485 communication interface. The isolation communication circuit is consisted of optocoupler and B0505S (a DC - DC converter), which separates the communication line and the separation line. The communication circuit adopts the 3-lines way, the control line CS, the output line TXD and the input line RXD. In the general case, CS is at a high level or an impending state, only a program control instruction can make it into low level state. This will ensure that when the controller power turns on or microprocessor controller is abnormal, they will not produce interference to the communication bus.

TVS is connected to the input port and the output port of B0505S to prevent the communication interface circuit from producing overvoltage. This can meet the requirement of the intrinsically safe. The communication bus circuit has resettable fuse, current-limiting resistance, which provide the protection between line and line, the line and the ground. It can prevent the communication chips from the damage of over voltage and surge.

4.3. The Input and Output Circuit

8-channel input circuits are exactly the same. The circuits introduce resettable fuse, current limiting resistor and TVS to prevent the optocouplers from overcurrent. Load resistance and filter capacitor are also introduced to improve the anti-interference ability of the input channels. 74 LS14 is connected to the output pins of optocoupler. It can shape the output signal of the optocoupler. After a 74LS14's inverting, the input signal and the output signal of 74 LS14 are consistent in phase. The input signals of the 8 channels enter into the data acquisition control microprocessors after shaping.

The output circuit mainly consists of the current-limiting resistor, the light emitting diode, the driving circuit, optcoupler, and 74HC595. 74HC595 drives the optocoupler though LED and current limiting resistor, providing the output instructions. The acquisition microprocessor controls 74HC595 to output control signal (power outages or complex signals).

4.4. The Communication between the Microprocessor Modules

The Microprocessor modules consist of the micro controller P89LPC936, the memory chip PCF8583, the regulator circuit LM117, the reset circuit, etc. Different programs are loaded to the different microprocessors to realize different functions such as controlling communication, data acquisition and data display. The three Microprocessors is connected through the I^2C bus (SDA and SCL), ACK1, ACK2. The controlling MCU receives the notification from other microprocessors through ACK. Then, it enters into the state of acquisition interruption. The signal from the acquisition MCU can set the data flag. After detecting the flag, the controlling MCU starts I^2C and read the data in RAM coming from the channels of output and input. The structure of the communication circuit is shown as Fig. 4.

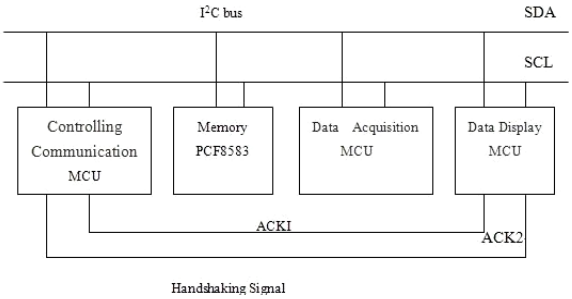

Fig. 4. The communication between the microprocessor modules.

4.5. Design of the Data Acquisition Program

The signal from sensors is binary signal in the state of 0 or 1 at a certain moment. The program

writes the new data from the input channel to New_P0 (a program variable), the last data to Old_P0. TD8 is regarded as the counter in the program. The XOR result of New_P0 and Old_P0 is written to Result_P0. TD8 will be incremented by 1 if Result_P0 is 0. Because TD8 is incremented at the rising and falling edges of the input frequency signal, the counting cycle is set to 500 Ms. The value of TD8 in a cycle is the value of the respective sensor. Data processing and the controlling output can be completed within 100 ms. Plus the millisecond relay, the entire time of reading input data, data processing and controlling output is less than 2 s. So it can satisfy the requirement of the controller.

4.6. The Operating Panel

To design an operating panel in the staff room of rescue capsule, the core of the panel is the ARM processor. Through the connection of the serial port and the controller, the ARM processor can read and displayed the data on LCD panel. The alarm threshold can be set through the operating panel. Through the operating buttons, the trapped miner can control device action directly to assist the automatic controlling system. The operating panel is shown as Fig. 5.

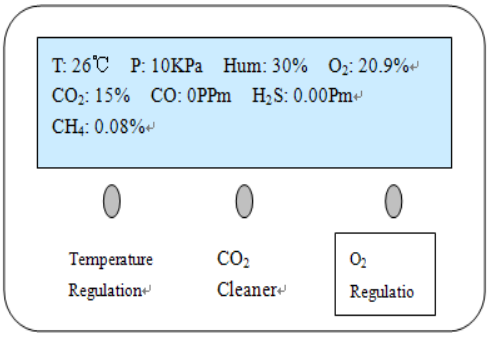

Fig. 5. The operating panel.

5. Conclusion

The developments of rescue capsule make the coal mine rescue enter a new stage. The controlling system of rescue capsule takes responsibility of monitoring the cabin environment and controlling the device inside. The controller is using the multiple processors technology. The processors exchange data through I^2C bus, which complete the job of data acquisition, communication, display and controlling output. It improves the real-time performance of the system. It is found that this design can fully meet the national requirements after experiments.

In the near future, the coal mine rescue capsule will be one of the important survival equipment for the coal mine in China. And it will be able to promote coal mine production.

References

[1]. Charles Vaught, Erica E. Hall, Katherine A. Klein, Mine refuge chamber training, *National Institute for Occupational Safety and Health*, USA, 2009.

[2]. Han Wen-Da, Liu Tie-Jun, Liu Gui-Qiang, et al., Development and tendency of refuge chambers for mine, *Coal Mine Machinery*, China, 2011.

[3]. The state administration of coal mine safety. Provisional regulations of coal mine emergency system construction management, *China Coal News*, China, February 16, 2011.

[4]. Sun Ji-Ping, The key technologies of the refuge chamber and rescue capsule in the underground coal mine, *Journal of the China Coal Society*, Vol. 36, No. 5, May 2011, pp. 713-717.

[5]. Yang Xudong, Jin Liangliang, Li Jiachun, Sun Dong, Design and analysis on the structure of coal mine rescue capsule, *Journal of Convergence Information Technology*, Vol. 7, No. 15, 2012, pp. 252-260.

[6]. Zeng Yi-Xin, Bai Chun-Hua, Li Jian-Ping, Chen Jian, Wang Zhong-Qi, Numerical simulation of rescue cabin under blasting in the tunnel, Meitan Xuebao, *Journal of the China Coal Society*, Vol. 37, No. 10, October 2012, pp. 1705-1708.

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