The Design of the Control System of Fire Control and Smoke Extraction Robot Based on PLC

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Abstract. The purpose of this paper is to design a plc-based control system of fire control and smoke extraction robot, which can realize the purpose of water cannon, vehicle body movement and non-line-of-sight operation. This control system is mainly composed of PLC control system, video system, remote control system, motor drive system. PLC Through CANopen message transmission protocol, the function of distributed control system is realized. The main task is to receive the CAN command of remote control, so as to realize the command control of vehicle body action (multi-way valve), yuntai action and water cannon action. The design meets the design requirements, has good operability and reliability, in the industry has a certain promotion significance.

1. Technical Background
As the largest tunnel market in the world, China is rapidly releasing its potential and has become the country with the most complicated and fastest development of tunnel and underground space projects in the world. In the past 10 years, due to the increasing length of the tunnel, the increasing traffic flow, the improvement of road conditions and the complexity of transporting goods, the fire risk of the traffic tunnel has been increased, causing many serious fire accidents. The proportion of people killed by smoke is as high as 80%. In the number of people killed by fire, most of them are killed by fire after poisoning, suffocation and fainting. In the number of fire deaths, the majority of the smoke-choking reaction resulting in death. Obviously, in the case of fire in the tunnel of public (railway) road and large underground space, effectively discharging smoke from the fire site is an important link to prevent the spread of fire, rescue trapped people and put out the fire, which has the following important significance.

2. The Overall Structure of the Smoke Extraction Robot
The fire fighting and smoke extraction robot system consists of two parts: the fire fighting and smoke extraction robot body and the hand-held wireless remote control. The firefighting smoke exhaust robot body is composed of mobile carrier, special spray smoke exhaust device, pump booster device, water filter device, floodlight, hydraulic system, hydraulic cooling system, control device and operation panel.

3. Hardware Design of Smoke Extraction Robot
Select the remote controller according to the environmental conditions and process control requirements. The functional requirements for the handheld wireless remote control must be met are shown in table 1. The remote control and the head camera are shown in figure 1. The duty cycle is 30%, the period is about 502US, and the frequency is about 2KHZ. This point voltage is DC13.12v, shown in figure 2.
Figure 1. The remote control and the head camera

Figure 2. Duty cycle corresponding voltage

Table 1. Functions of handheld wireless remote control buttons

| NO. | Button to define     | Functions                                                                 |
|-----|----------------------|---------------------------------------------------------------------------|
| 1   | The power supply     | Start the handheld wireless remote control power supply                   |
| 2   | Scram button         | In case of emergency, operate the robot to stop, remote control power     |
| 3   | The Right of         | Operate the robot to move forward                                          |
|    | Rocker forward       |                                                                           |
| 4   | Rocker back          | The operating robot walks backwards                                        |
| 5   | operation Turn left  | The operating robot turns left                                             |
| 6   | Turn right           | The operating robot turns right                                            |
| 7   | Turn the fan on/off  | Operate the opening or closing of the special spray exhaust device for the robot |
| 8   | Fan up/fan down      | The pitch motion of the special spray exhaust device for the operation robot |
| 9   | Turn the pump on/off | Operate the robot pump on or off                                           |
| 10  | Turn lighting on/off | Operate the opening or closing of the robot lights                         |
| 11  | Open/close           | Operate the opening or closing of the external hydraulic interface of the robot |
| 12  | Dc/spray             | When equipped with dc/spray water cannon, switch the spray state          |
| 13  | Start/stop           | Operate the robot to start or stop                                         |
| 14  | Acceleration/deceleration | Operate the engine speed up or down on the robot                       |
| 15  | High/low speed       | After the robot starts, switch the high and low gear of the mobile carrier |
| 16  | Zoom plus/zoom minus| Zoom of cradle head camera                                                |
| 17  | The Right of         | Head camera up                                                             |
|    | Rocker up            |                                                                           |
| 18  | Rocker down          | Head camera down                                                           |
| 19  | Rocker left          | Head camera left                                                           |
| 20  | Rocker right         | Head camera right                                                          |
4. The Program Design of Smoke Extraction Robot

When the ambient temperature is lower than 5°C, manual preheating must be carried out first. The preheating switch is the manual start switch on the operation panel. The temperature sensor outputs 4~20mA current signal, and the detection temperature range is -20°C ~130°C. According to the Hesmor controller G19 PLC manual[1], it can be known that when the analog signal is input into the PLC pin, the bare data of the 4-20ma current signal corresponding to the PLC input variable is 0-1023. In order to more fully study the change of PLC internal variables with the change of external temperature, so through MATLAB software calculation, simulation, An objective function can be obtained:

\[ T(\text{Output}) = (\text{Output}) \times 14.66 - 3000)/100 \]

The robot adopts the high-power special spray smoke exhaust device (hereinafter referred to as fan) with the maximum air volume up to 90000m³/h, and realizes the important functions of long-distance air supply, smoke exhaust, water mist fire extinguishing and cooling, dust removal, attack and cover against dangerous targets. The maximum air volume is 90000m³/h, and the engine speed is required to reach 2200R/M. In order to fully study the variation of PLC internal variables with external pulse, an objective function can be obtained through MATLAB software calculation and simulation:

\[ S(\text{Output}) = \text{Output}/129 \times 60 \]

A large number of experiments show that: the temperature and the transmitter speed of the field instrument and secondary instrument data consistent, the data model is established correctly, the data is stable, can be used as the PLC program design function.

5. Main Programming

The functions of the main program include system initialization, diesel engine starting, analog quantity processing, fan control, walking control, speed conversion, fault processing. It has configuration and scripting techniques[2]. This logic design method and relay control circuit are converted to trapezoidal design method [3].

5.1 Initializes the Program Design

5.2 Walk Control Program Design
5.3 Analog Processing Program Design

5.4 Diesel Engine Starting Program Design

5.5 Fan Control Program Design

5.6 Speed Conversion Program Design
5.7 Acceleration and Deceleration Program Design

5.8 Fault Handler Program Design

5.9 Control Program Design of Head
5.10 Configuration Screen Data Display Program Design

5.11 Program Monitoring and Debugging and Hydraulic Test of Fire Engine
The control process of smoke extraction robot is analyzed and studied, and the control program of the process is designed. The field instrument display, rear configuration data display and data monitoring of smoke extraction robot are consistent and stable. To meet the actual work needs of fire protection, to achieve the goal of promotion and application[4], with good social and economic benefits[5].

Program monitoring is shown in figure 3, hydraulic system test of fire engine is shown in figure 4.

![Program monitoring](image1)

![Hydraulic system test of fire engine](image2)

Figure 3. Program monitoring is shown

Figure 4. Hydraulic system test of fire engine
6. References

[1] Mathias Schreyer, Systematic software design for PLC operated automation systems[M]. Hong Kong University of Science and Technology, 2001.

[2] Gongbo Zhou, Zhencai Zhu. Technique of WinCC Long-distance Accessing Exterior SQL Server Database[J]. 2009 First International Workshop on Education Technology and Computer Science: 153-155.

[3] Frey G, Litz L. Formal methods in PLC programming[C]. IEEE International Conference, 2000, (4): 2431-2436.

[4] Mei Dacheng, He Zhimin, Gong Jie. Research and implementation of building distributed control system based on S7-200 PLC and PC. IEEE Proceeding, 2010: 230-297.

[5] Hongwei Jiao. Multifunctional emergency plugging test and simulation training method. ICCAES2019. 2019: 222