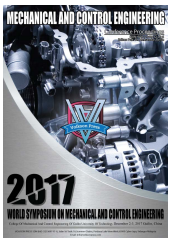
ISBN: 978-1-948012-06-5

Contents List available at VOLKSON PRESS

World Symposium on Mechanical and Control Engineering (WSMCE)



DESIGN OF HIGHLY RELIABLE LOGIC CONTROL SOFTWARE FOR ESCAPE SYSTEM IN PRE-LAUNCHING STAGE

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ARTICLE DETAILS

Article History:

Received 02 october 2017
Accepted 06 october 2017
Available online 11 november 2017

Keywords

PLC, Control design, Emergency escape, High reliability

ABSTRACT

In order to meet the sudden danger of manned launch vehicle on the ground, emergency escape control design in the pre-launching stage should ensure high reliability and high safety. Based on programmable logic control combination (PLC), a logic control software design was proposed. By constructing 'data input module', 'logic control module' and 'function module', emergency escape commands could be transmitted accurately; at the same time, combined with redundancy design, filtering design and other reliability design measures, the goal of occupying less system resources and high efficiency has been realized, which could guarantee that astronauts escape quickly and reliably at the first time of danger.

1. Introduction

With the steady progress of Chinese manned space "three steps" strategy, the manned launch vehicle technology represented by "CZ-2F" has made great achievements in the past decade. Launch vehicle technology has developed rapidly, and the safety and reliability of the rocket has gradually increased [1]. In the pre-launching stage of manned rockets, the ground escape control system design is the key problem to ensure rockets safe in order to meet various sudden failure modes such as rocket dumping, fire and etc. As the core part of the system software, programmable logic control software (PLC software) for emergency escape control system is responsible for receiving escape, unlock and test instructions, and sending escape instructions to fault detection system after logical judgments, which allows astronauts could escape reliably and quickly.

In this paper, PLC+ embedded control program was used to replace the analog circuit of 'button switch + relay' for the original system, and the design scheme of escape command software was given. At the same time, using redundancy, filtering and other reliability design measures, the reliability and scalability of the system was improved, and the accuracy and safety of emergency escape was ensured. This software occupies less system resources, and has high efficiency, which meets the needs of emergency escape control system in pre-launching stage [2]. It will play an important role in manned space engineering.

2. OVERALL DESIGN OF PLC SOFTWARE

2.1 Software structure

PLC software was designed based on GE Machine Edition 8.0 environment, mainly including "data input module", "logic control module", and "function module".

a) "Data input module" includes "instruction receiving sub-module" and "state signal receiving sub-module", which are respectively responsible for receiving the control command signals issued by the control computer application software and the state signals from the control panel and the front equipment of fault detection system;

b) "Logic control module": could complete the logical judgment, and send out the wire escape command and test instruction through "main logic sub-module";

c) "Function module": contains two functional sub-modules, which respectively completes the PLC cumulative power record and PLC work status indicator function.

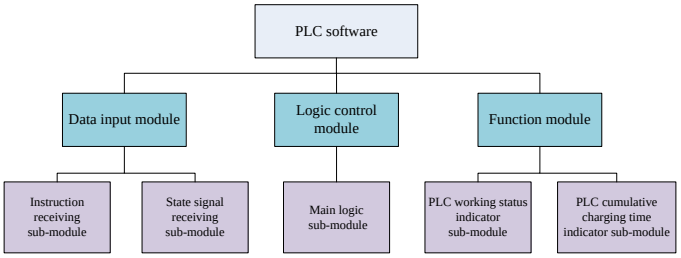

Figure 1: Structure of PLC control software

2.2 Software data architecture

As shown in Fig. 2, CPU of control combination PLC receives the instruction variable%Q from the control computer through Ethernet, and returns the state variable%Q, data variable%R and analog%AI. The switch variable input module receives the instruction variable%I issued by the control panel, and outputs the instruction variable%Q to fault detection system through the switch output module.

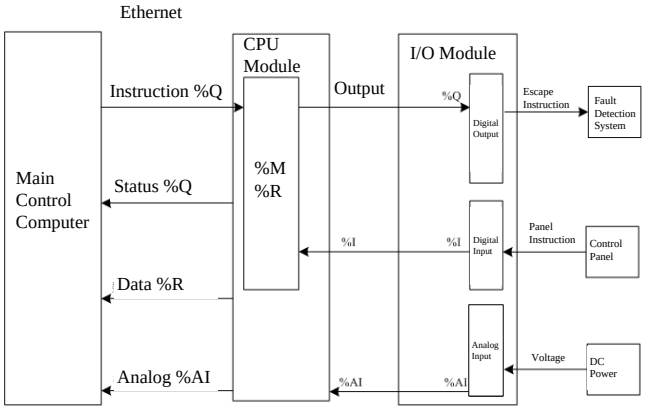

Figure 2: External interface information flow chart of control system

3. DESIGN AND IMPLEMENTATION OF SOFTWARE MODULE

3.1 Instruction receiving sub-module

The sub-module is responsible for receiving the escape command issued by the main computer software, and also can detect the validity of the input command signal, which could improve the reliability and anti-interference ability of the software.

When the master computer software sends command signals to the PLC control software, each instruction is bursted 3 times at the frequency of 100 ms/frame, and the instruction is written to state amount register [3]. If PLC software receives 2 frames in one second, it is specified effective; if not, it has to wait for receiving command signal again after the time reset.

3.2 State signal receiving sub-module

This sub-module is responsible for receiving state signals issued by the control panel and fault detection system, including state signals of "TY0 unlock (main)" , "TY0 unlock (ready)" , "TY1 escape ", "TY2 escape", "TY3 test", "test/launching", "rocket allowed escape", "spacecraft allowed escape" and "ground allowed escape" from the control panel, as the same as "fault escape instructions " and "escape instruction received", "Plug connected indication" and "escape allowed by fault detection" from the fault detection system.

The state signals of "rocket allowed escape", "spacecraft allowed escape" and "ground allowed escape" use one single switch input module to receive signals, and the rest state signals respectively use 3 switch input modules. The PLC software makes the judgment by "2-out-of-3 voting".

3.3 Main logic sub-module

The sub-module is responsible for logical judgment, and to send wire escape instructions and test instructions. Escape command logic is designed in the control software to avoid missing escape or fault escape. The logical judgment relation is shown in figure 3.

- "rocket allowed escape", "spacecraft allowed escape" and "ground allowed escape" are all the necessary conditions to the final escape unlock instruction;
- The sending of escape instructions and test instructions is constrained by escape unlocking command;
- Test status and launching status are mutually exclusive. Test status can only send test instructions, and escape instructions can only be issued by launching status.

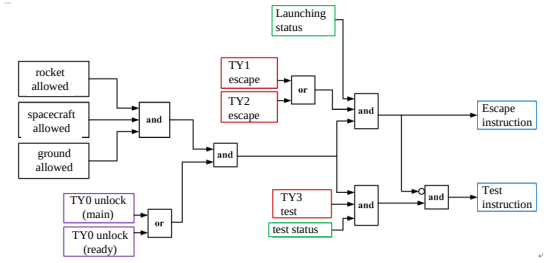

Figure 3: The logic control relationship of PLC software

3.4 PLC working status indicator sub-module

The sub-module is responsible to indicate the PLC work status and to send the PLC working status to the main control software [4]. Figure 6 shows a screenshot for programe.

Figure 4: Programe of PLC working status indicator sub-module

3.5 PLC cumulative charging time indicator sub-module

The sub-module is responsible for counting the cumulative charging time of PLC, and sending the result to the master software. The maximum charging time of PLC software is 500h, and time will be cleared again if more than 500h. Figure 7 shows a screenshot for programe.

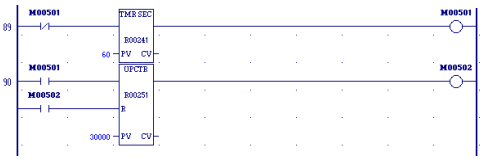

Figure 5: Programe of PLC cumulative charging time indicator sub-module

4 RELIABILITY DESIGN

4.1 Reliability design of data input

The PLC software receives the instruction signal sent by the main control software, and adopts the method of "2-out-of-3 voting"to prevent error triggering [5]. The PLC software receives state signals from the control panel and fault detection system, using "series and parallel connection" approach to select 2 from 3. At the same time, the state signals are set as maintaining signals, and only signals lasting more than 100ms are considered valid by filtering method. This method can avoid error command input, and guarantee the reliability of receiving information.

4.2 Reliability design of instruction output

The main logic sub-module of PLC software uses redundant design to output important instructions, and "rocket allowed escape", "spacecraft allowed escape", "ground allowed escape" instructions use parallel redundant design of control panel and master control software instructions. Escape output logic is designed in the main logic module. When "allowed escape", "unlock" and "launching state" instructions are effective at the same time, it can send wired escape instruction.

The wired escape command adopts "double output" and "serial and parallel design", which can ensure that the control command can still be sent out if one way is fault, so as to avoid the risk of "missing escape".

4.3 Reliability design of system resource utilization

The intermediate variables are independent of each other, and each variable address is far apart. Thus there is no wrong operation problem,and that improves the reliability of the software. At the same time, using the working principle of PLC scanning cycle, PLC status indicator sub-module uses a timer to output a square wave of 4s cycle and 50% duty cycle. Compared with traditional scheme of 2 timers, this method can prevent the software preemption of system resources, and avoid resource depletion.

5 CONCLUSION

The PLC software for emergency escape control in pre-launching stage uses input mode of "2-out-of-3 voting" and 100ms filter design, and this effectively prevents the misuse of receiving instructions. Switch output selects series and parallel redundancy design to avoid "missing instruction" problem. The PLC software design can significantly improve the reliability of escape control system, and shorten the processing time of fault. Meanwhile, it can also reduce the risk in the pre-launching stage, and meet the needs of manned space flight mission. Thus, this software has high economic and social benefits.

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