CHEMICAL ENGINEERING TRANSACTIONS
VOL. 59, 2017
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Zhuo Yang, Junjie Ba, Jing Pan

ISBN 978-88-95608- 49-5; **ISSN** 2283-9216
DOI: 10.3303/CET1759101

Design of Automatic Fire Alarm System in Workshop of Chemical Plant

Rui Wang*, Ying Chu, Luqi Bi

College of Chemistry and Chemical Engineering, Yanan University, Shaanxi 716000, China
52016768@qq.com

With the continuous development and application of new technologies and new products, Chemical plant reconstruction and expansion projects continue to increase. In addition, chemical production itself has flammable, explosive, toxic, harmful, corrosive and other characteristics, the potential risk factors increased, factory fires occur frequently. Therefore, in order to ensure the safety of life and property, a set of convenient automatic fire alarm system is designed for the workshop of chemical plant. Firstly, the system detects abnormal signals from three aspects of temperature sensing detector, smoke detector and photosensitive detector. The measuring signal is then transmitted to the PLC centralized control center via a transmitter, the controller makes a quick decision according to the preset program and sends out the corresponding control signal. If there is a fire, start the automatic fire extinguishing system and smoke exhaust system at the same time as the alarm, finally, the fire is nipped in the bud. The system uses one to many signal docking to facilitate the use of different places, and each detection area system has more than two different alarms to prevent false negatives and false positives. It is not only suitable for the use of a petrochemical factory, but also can be used in schools, warehouses, offices and other places.

1. Introduction

With the rapid development of chemical industry, the demand for chemicals, raw materials and related products has increased, and the possibility of fire accidents in the process of production, storage and transportation has increased, and the potential risk factors have increased accordingly (Gao, 2011). Therefore, the design of a convenient fire alarm system is particularly important that can effectively prevent and control the fire so as to ensure the safety of life and property. At present, the detectors used in large alarm systems in China have good performance, but the system is huge, the detection device is complex, and the price is expensive, so they cannot be widely used for a long time. The traditional fire alarm system is simpler and lower cost, but the false positive rate and false negative rate are higher (Liu, 2005). Therefore, in view of the current situation, a small and convenient fire alarm system is designed in this paper. It uses PLC as the control center, PLC judges the signals transmitted by smoke detectors, light detectors and temperature sensors quickly and accurately, and outputs control signals, if there is a fire, it can start the automatic fire extinguishing system and smoke exhaust system at the same time as the alarm. Finally, the fire is nipped in the bud. The system uses one to many signal docking, it is mainly used in the workshop of a chemical plant, and more than two different alarms are arranged in each detection area to prevent the omission and false positive phenomena. The system is simple, economical and applicable.

2. Design of automatic fire alarm system

2.1 General frame design of automatic fire alarm system

The overall design frame of the automatic fire alarm system is shown in Figure 1. When the system is installed in the workshop, and system is initialized after system check without error, fire detectors begin to work to detect the monitoring site status. When a danger has been detected, fire detectors transmit measurement signals (manual alarm signals) to the PLC control terminal, the PLC issues control instructions by analyzing operations, the sound and light alarm receive the PLC outgoing signal, and then calls the police, at the same

Please cite this article as: Rui Wang, Ying Chu, Luqi Bi, 2017, Design of automatic fire alarm system in workshop of chemical plant, Chemical Engineering Transactions, 59, 601-606 DOI:10.3303/CET1759101

time, automatic fire extinguishing devices (also equipped with manual switches, combined with automatic control) have also begun firefighting.

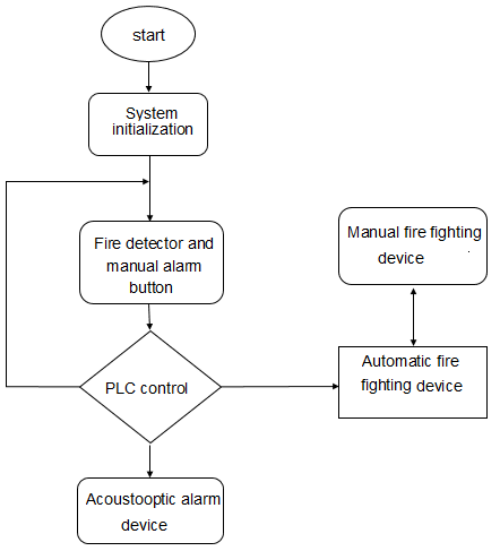

Figure 1: General design of automatic fire alarm system

2.2 System hardware design

The hardware design is an important component of the control system. This section mainly includes the design and selection of the detection device, the alarm device and important components in the fire protection equipment (no special requirements of hardware is not in this type of selection).

(1) Selection of temperature sensing detector

The detector that is used as a detecting device to input the signal into the PLC control center is the eyes and ears of this system, which is especially important. For the fire hazard in different places, the proper detector can not only predict the fire, but also save the cost. The research object of this paper is the workshop of chemical plant, the fire alarm system adopts a differential constant temperature detector, namely Shenzhen Orin song Technology Co. Ltd. OR-H707 temperature sensing detector, a unique scaffold design, with anti-demolition work, convenient installation, no polarity four wire, network output, low power consumption (Dou, 2005), NC/NO optional compared with other companies, the quality of higher quality, more appropriate

(2) Selection of smoke detector

Smoke fire detector is suitable for installation of smoke generated larger or prone to smoldering in place after the fire, and it should not be installed in peacetime, large smoke or ventilation faster place. Most of the fire in the workshop of the chemical plant is caused by the fire of the electric line, the leakage of inflammable and explosive gas or liquid, careless use of fire, etc, moreover, when toxic gas leaks, poisoning may occur, thereby threatening the safety of life. There could be an explosion, such smoke detectors can detect smoke signals in a timely manner and react sensitively (Chen, 2002). This design uses the switch network smoke JTY-GD-DJ311C of the Kai Wei letter, according to technical requirements, switch network smoke sense is the most appropriate. This product has the characteristics of high sensitivity, stability, reliability, low power consumption, beautiful and durable, it is easy to use and so on. Relay passive contact output can be set, the smoke chamber is designed with insect screen in order to avoid insects into the alarm, it is cost-effective.

(3) Selection of light sensor

The photosensitive detector is applied to a fire alarm with an obvious flame. It should be installed in a place where explosion happens at once, such as oil, explosives and other chemical manufacturing, storage sites, etc. Of course, all fires will have flames, and detectors will be used more widely. This design uses the JTG--GZFST9724 point type ultraviolet flame detector of Haiwan, UV sensitive tube with advanced technology is selected, it has the advantages of high sensitivity, reliable performance, the advantages of anti dust pollution, anti moisture and strong corrosion resistance, and has three sensitivity settings (Liao, 2013). It applies to sites with varying levels of interference and has advantages over other products.

(4) Selection of alarm device

Now the detection devices are usually detected after the exception, the output of early warning signal is for on-site alarm and remote alarm. The design uses remote alarm, remote alarms are installed where the staff is easy to see or hear, so as to ensure timely detection of fire and rescue. It can avoid the fire scene no one

present, causing serious loss of property or trapped personnel, or the outside can not be promptly rescued.
The alarm device selects the sound and light warning lamp. When a fire is detected or a fire is imminent, the sound and light alarm will give an alarm sound, and the indicator lamp will stop flashing. It need to be installed where the staff is easy to see or hear, at the same time, it can avoid the glare around the alarm, high power, noise, etc. This ensures that when the personnel do not see the alarm flashing, you can hear the sound of the alarm, as soon as possible evacuation. This design uses the LTE-5101J LED heavy of Ya song alarm lamp (Siemens, 2004).
(5) Selection of fire fighting device
Different fire fighting treatments are carried out for different fires, of course, automatic fire extinguishing systems can only carry out early fire fighting to prevent fire from spreading, it can gain time for artificial fire fighting. Therefore, the system is only equipped with smoke exhaust system and sprinkler system.
The smoke exhaust system is designed to prevent the leakage of flammable gases and toxic gases, to prevent staff poisoning or smoldering items cause suffocation. For example, when the smoke detector enters the field signal into the PLC control box, the PLC control center will signal the switch of the smoke exhaust system.
Sprinkler fire is a means of fire in most fires, the PLC control center controls the flow of water by controlling the solenoid valve in the pipe. The solenoid valve is normally closed. When the PLC control center sends out a signal, the solenoid valve opens and fires are put out. The system uses the installation of high position water tank to provide water sources. Of course, it can also directly use the water pipe, but because the supply of water supply is uncertain, cannot guarantee foolproof, therefore, the device consists of two water measuring electrodes, a centrifugal pump and a water tank, which form a simple fire water source.
No matter which detector detects fire, the PLC control center also signals the total power supply to be cut off (Non fire alarm system line), Because the market smoke exhauster, centrifugal pump, water measuring electrode and solenoid valve can be used, so there is no selection.

2.3 The design of system software

2.3.1 The choice of programmable logic controller

The input signal of this device is the critical value signal detected by each alarm, data collection is not necessary, the main control objects are the alarm, the smoke exhaust system in the fire extinguishing device and the on-off of the electromagnetic valve, both input and output are switches. The programmable controller PLC and the monolithic integrated circuit may complete the task, but PLC has the advantages of simple wiring, fast processing speed, simple operation, easy operation and high reliability. It is more suitable to be chosen as the control unit of this system (Siemens, 2007).

2.3.2 Corresponding naming of control points

Each of the devices in Table 1 corresponds to the PLCI/O interface terminal, the smoke detector signal F0 is connected to the PLCI0.0 interface terminal. The light sensing signal F1 is connected to the PLCI0.1 interface terminal. The temperature sensing signal F2 is connected to the PLCI0.2 interface terminal. The low water level signal F8 ofwater tank access PLCI1.0 interface terminal. The high water level signal F9 of the water tank is connected to the PLCI1.1 interface terminal. The PLC output terminal Q0.0 controls the switch of the Y0 alarm, Q0.1 controls the switch of Y1 smoke exhaust system, Q0.2 controls the switch of the Y2 sprinkler, Q0.3 controls Y3 normal power switch, Q0.4 controls the switch for the Y4 alarm, F3, F4, F5, F6, is the reset signal. F7 is the manual alarm button that connects to the PLCI0.7 interface terminal, This button is mainly man-made remote alarm.

Table 1: Naming table of control point

Input signal		Output signal	
F0 Smoke detector signa	I0.0	Y0 Alarm lamp switch signal	Q0.0
F1 Light sensor signal	I0.1	Y1 Switch signal of smoke exhauster	Q0.1
F2 Temperature sensitive detector signal	I0.2	Y2 Solenoid valve switch signal	Q0.2
F3 Warning lamp reset signal	I0.3	Y3 Total power switch signal	Q0.3
F4 Reset signal of smoke exhauster	I0.4	Y4 Alarm lamp switch signal	Q0.4
F5 Sprinkler head reset signal	I0.5	Y5 Switch signal of centrifugal pump	Q0.5
F6 Total power reset signal	I0.6		
F7 Manual alarm signal	I0.7		
F8 Water tank low water level signal	I1.0		
F9 High water level signal of water tank	I1.1		

2.3.3 PLC model selection

The device is provided with a smoke detector, a photosensitive detector, a photosensitive detector, a manual alarm button, and a high and low water level signal as input. Therefore, 6 input interfaces are needed, 4 stop input interfaces and 6 output interfaces are set up in 4 starting and stopping circuits.
According to the control and design requirements of the equipment, the system requires 16 I/O points for the control unit, and you need to reserve space for expansion and upgrading, through the analysis of each type of PLC, select SIEMENS's S7-200CPU224.

2.3.4 Design of PLC program

To achieve the control function of the system, you need to write applications, Because of the more content, it is no longer listed in detail here.

2.3.5 PLC external wiring instructions

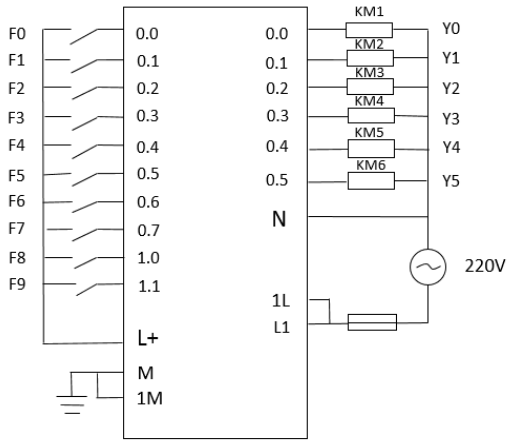

Figure 2: PLC external wiring diagram

Figure 2 is an external connection diagram for this system, it is combined with table 1 to visually and clearly understand how each part is wired to the PLC control panel.

3. Analogue simulation

The design uses SIEMENS S7-200 simulation software for simulation, the software can emulate a large number of S7-200 instructions, check that the program is accurate. The input signal of this software is artificial instead of automatic signal for input simulation, and the specific simulation process is discussed as follows.

3.1 Simulation of a single warning signal

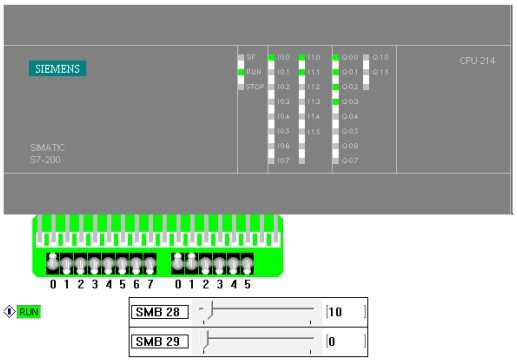

Figure 3: The simulation diagram of smoke detector warning

It needs to open the S7-200 simulation software and load the program written in V4.0 STEP 7 MicroWIN SP9 software, then boot emulation changes from STOP state to RUN state. When the F0 smoke detector detects

that the smoke reaches the set concentration, the signal is sent to I0.0, the Q0.0 coil is energized, the Y0 alarm lamp flashes and the timer is started. If the monitoring personnel determines the fire, no reset operation, ten seconds timer on delay Q0.1, the Q0.2, Q0.3 coils are energized, Y1 smoke exhauster opens for smoke evacuation, Y2 electromagnetic valve opens sprinkler head for sprinkler fire fighting, Y3 non fire system power on, power off, as shown in figure 3.

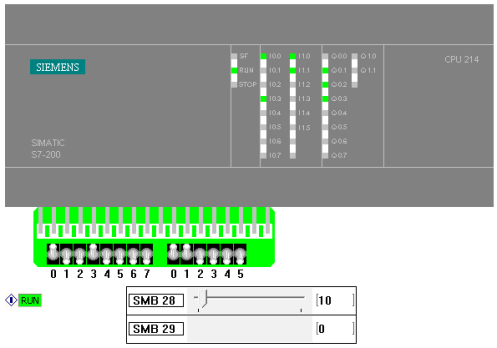

Figure 4: Alarm light reset simulation

When the staff found the fire and evacuated, you can Press the F3 alarm light reset button at this time, and turn off the alarm, Q0.0 loop power off, the Y0 alarm lamp stops working, as shown in Figure 4. When the fire has been destroyed, you can press the F4, Q0.1 power off, the smoke exhauster stops working, press F5, Q0.2 power off, Y2 solenoid valve closed, press F6, Q0.3 power off, complete system reset. Of course, the three fire operations do not affect each other, and when dealing with the fire, the switch of each part can be controlled according to the situation.

Between the three F0, F1, and F2, only one detector detects a fire signal, or F7 sends an early warning signal (consider manual alarm, may be wrong to press, so the signal should be confirmed processing), the system runs as described above, don't go into details here.

3.2 Simulation of multiple detection signals

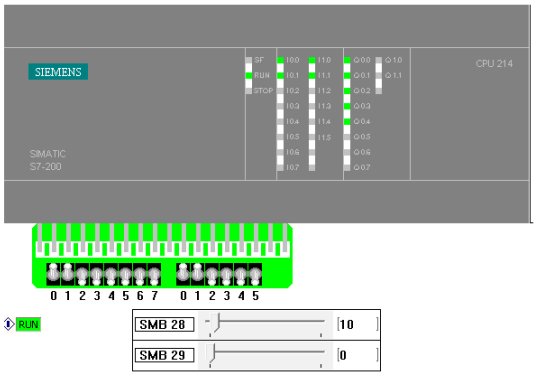

Figure 5: The simulation diagram of somoke sensitive detector warning

As shown in Figure 5, F0 and F1 send warning signals at the same time, then the coils are energized by Q0.0 and Q0.4. Y0 and Y4 alarm simultaneously. Coils Q0.1, Q0.2 and Q0.3 are energized. Y1 begins to exhaust smoke. Y2 begins to open sprinkler head and fire water. Y3 power cuts off. Similarly. F0 and F2 send warning signals at the same time; F1 and F2 send warning signals at the same time; F0, F1 and F2 send warning signals at the same time; F0 and manual alarm send warning signals simultaneously (each detector is connected with manual alarm in series); F0, F1, F2 and manual alarm send warning signals at the same time, the results are similar to those shown by both F0 and F1 at the same time. When the fire occurs and is found by the staff, press the F3 alarm light reset button, the coil Q0.0 and Q0.4 coils are powered down, two alarm lights stop working, other reset operations are the same as when a single signal is early warning. This series of monitoring signals are used in series, which can greatly reduce the false positive rate.

Simulation is performed by SIEMENS S7-200 simulation software, it verifies the correctness of the PLC program and ensures that the system works properly and is consistent with the expected results.

4. Conclusions

Through this design, it realizes remote automatic alarm and automatic fire control by using PLC as the control center. The system is easy to use and maintain, complete in function, safe and reliable in operation, simple and practical, economical and convenient. Although the automatic fire alarm system in this paper is mainly designed for the production workshop of the chemical plant, but today, with the rapid development of science and technology, PLC has enough room to prepare for other intelligent controls in the future. If it is centralized control, it can make room for anti-theft system. In addition, PLC is widely used and has strong control ability, so it has good prospects for development.

Acknowledgments

This work is supported by National College Students Innovation and entrepreneurship training program: Research and development of Indoor Intelligent dust removal windows (No. 201610719032); The scientific research project of Yan'an University: Research on safety monitoring and alarming system of petrochemical plant based on WSN and GPRS (No. YDQ2014—31); Chemical and Chemical Engineering Institute of Yan'an University (No. YDHG2014-Z05); Research project to educate people of Yan'an University: Investigation on sustainable development of energy and chemical base in Northern Shaanxi Province (No. YDZZYB16-13); Research project of teaching reform in Yan'an University: Reform and practice of teaching mode of process equipment and Control Engineering Specialty (No. YDJG2016-15); Classroom teaching reform project of Yan'an University: Classroom reform of process equipment control technology and Application (No. KTJG2017-75).

Reference

Chen Z.P., Zhao X.B., 2002, Programmable logic controller technology and application system design, Beijing: Machinery Industry Press, 100-102.

Dou L.X., Xin Y.Z., 2005, Measures against false alarming produced by fire automatic alarming system, Journal of The Chinese People's Armed Police Force Academy, 21(4), 22-23. Doi: 10.3969/j.issn.1008-2077.2005.04.006

Gao L.L., 2011, Research on automatic fire alarm system based on wireless transmission module, HeBei University of engineering, 5-10. Doi: 10.7666/d.d153385

Liao C., 2013, PLC programming and Application, BeiJing: Machinery Industry Press, 120-128.

Liu P.L., 2005, Intelligent locomotive fire detection system, National University of Defense Technology, 15-20.

Siemens, 2004, SMATIC Programming with STEP7 V5.3 Manual, SIEMENS.

Siemens, 2007, SMATIC S7-200 Programmable Controller System Manual, SIEMENS.

Yu P., 2016, Design and implementation of automatic fire alarm system, Electronic Technology Software Engineering, 148.

Yu Y., Xu M.Z., Zhou X.B., Zhou H.N., Zhang Y., 2017, Design of electrical fire alarm system, Shandong Industrial Technology, 167. DOI: 10.16640/j.cnki.37-1222/t.2017.04.147