Analysis and design of integrated intrusion detector performance testing system

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Abstract. The integrated intrusion detector performance testing system is mainly used to simulate the performance of active infrared, passive infrared, infrared and microwave composite detectors. The device has the advantages of complete function, simple operation, stable performance, high control precision, accurate collection and good security. In addition, the wireless transmission technology is adopted, and the remote operation can be carried out. The main purpose of this paper is to develop the intrusion detector detection system according to the standard technical requirements and test methods, to meet the needs of product detection, and finally to improve the competitiveness of domestic related enterprises in the international market. The device can test whether the intrusion detector has the problem of false alarm and false alarm, test the anti-interference ability and the performance parameters of the intrusion detector, and then improve the product quality of the intrusion detector. It is very helpful to develop new products.

1. Introduction

With the rapid development of economy and the increasing improvement of people's living standard, people are demanding more and more safety, and the understanding of security and security prevention system is becoming more and more profound. In the intrusion alarm system, the main control unit has been relatively mature in technology, in the future will be integrated more ways, combined with network, cable, wireless integration and other directions. The detector technology is varied and the space for research and development of the technology is relatively large. Therefore, the innovation of intrusion alarm system is embodied in the technical change of the detector.

Intrusion detector as the most important detection device of anti-theft alarm system also has a rapid development. The domestic market mainly consists of active infrared detector, passive infrared detector microwave and passive infrared composite detector magnetic switch detector\textsuperscript{[1]}. As a key part of the whole alarm system, intrusion detection determines and affects the performance of the alarm system to a large extent\textsuperscript{[2]}, such as detection range, detection sensitivity, false alarm rate, etc. So it is necessary to detect the performance of the intrusion detector. In the course of many years' research and development, the problems of false alarm, false alarm and interference have always been the technical problems that need to be solved in the anti-theft alarm system industry\textsuperscript{[3]}. For these problems the...
corresponding detection methods, detection standards, detection instruments have been launched and constantly improved, how to effectively design a set of intrusion detector simulation test equipment is particularly critical. The device can test whether the intrusion detector has the problem of false alarm and false alarm, test the anti-interference ability and the performance parameters of the intrusion detector, and then improve the product quality of the intrusion detector[4]. It is very helpful to develop new products. Therefore, the development of intrusion detector inspection equipment has a very practical significance.

At present, there is a lack of integrated detection equipment for intrusion detection performance in the market. As far as our province is concerned, there is no inspection organization that can do the testing of this kind of products. Therefore, our main goal should be to develop intrusion detector detection system according to the standard technical requirements and test methods, to meet the needs of product detection, and finally to improve the competitiveness of domestic related enterprises in the international market.

2. System architecture and design principle

2.1. Performance test device of active infrared intrusion detector

The performance test device of intrusion detector is mainly used to simulate the performance test of active infrared intrusion detector. It is composed of frequency conversion motor, deceleration mechanism, rotating chain, cylindrical object, special installation fixture, safety protection device, rotary table, optical power meter, etc. According to GB 10408. 1-2000 standard, the transmitter angle test (as shown in figure 1), receiver angle test, response time test and detection range test are carried out. In the process of related tests, the detector is observed to alarm, and the test sample is judged to be up to standard [5].

![Figure 1. Principle diagram of transmitter beam angle.](image)

The rotary table is mainly used for angle test of transmitter and angle test of receiver. The rotary table is mainly composed of stepping motor, stepping driver, converting gear and rotating disk. The stepper motor is an open-loop control unit which converts the electric pulse signal to angular displacement or linear displacement by changing the gear to drive the rotating disc (indicated by the scale on the disk). In the case of non-overload, the speed and stop position of the motor depend only on the frequency and the number of pulses of the pulse signal, and are not affected by the change of the load, when the stepping driver receives a pulse signal. It can drive the stepping motor to rotate a fixed angle according to the set direction, and can control the angular displacement by controlling the number of pulses, so as to achieve the purpose of accurate positioning. Positioning accuracy is determined by the step angle and the fine fraction on the drive[6].

The test should be carried out in the darkroom, with the transmitter giving priority to DC power supply with a rated voltage of 12 V (or AC power supply with a rated voltage of 220 V). The transmitter is fixed on the workbench so that its optical system node passes through the center of the workbench roundabout. At a distance of 5m from the transmitter, an optical power meter probe is placed so that photosensitive surface is perpendicular to the optical axis O-O', and the transmitter is fine-tuned to maximize the output of its optical power. Write down the reading P1, and then turn the worktable to the left to the right by 15 degrees, respectively. The radiative power P2 and P2' of the
O-O" and O-O" transmitters are measured by the optical power meter, and the maximum values are taken between them.

According to the formula \( N = 10 \log (P_1 / P_2) \), the value of N should be more than 20 dB. After that, the transmitter is rotated 90 degrees along the O-O′ axis, and the radiation power values on the plane perpendicular to the original test plane can be obtained by repeating the above tests. The test and calculation results should still meet the requirements of this standard.

The single-chip microcomputer is used to control the stepping motor to drive the rotation angle of the worktable. The angle of rotation is obtained by the encoder and transmitted to the single-chip microcomputer system and finally to the PC for display. The optical power meter is selected according to the range of beam power transmitted by the transmitter, and the value obtained by the optical power meter can also be transmitted directly to the PC for display. Finally, the results of two records are used to calculate whether the final results meet the requirements. The schematic diagram is shown in figure 2.

![Figure 2](image-url)

**Figure 2.** Control principle block diagram of angle test for receiver.

2.2. Response time measurement

According to GB 10408.1-2000 standard, the response time test is carried out at the detection distance specified by the manufacturer. The transmitter and receiver are fixed at both ends, and the distance between the supports can be adjusted arbitrarily. The cylindrical object is fixed with a special mounting fixture in the rotating chain, which drags the metal barrel through the beam at a predetermined speed. The frequency conversion motor is connected with the chain through the reducer, and the frequency conversion motor accelerates in a certain time, which reduces the impact of the cylindrical object and has the function of safety protection. The cylindrical object achieves the set speed and then supplies the power to the detector, avoiding the influence of the velocity not meeting the requirement on the test results. The whole control system can monitor the test results by remote operation and ensure the safety of the testers.

In adjusting the beam axis between transmitter and receiver, a cylindrical object with a diameter of 200mm, its length should be able to fully block the beam and pass through the beam at a speed greater than 10m/s perpendicular to the beam axis. The detector should not produce an alarm state. When the object passes through the beam at a speed less than 5m/s, the detector should generate an alarm state and calculate the alarm duration. When the detector operates at the detection distance specified by the manufacturer, the duration of the radiation signal being completely or partially obscured by a given percentage of the detector shall be greater than 40 (1 ±10%) ms, detector shall produce an alarm state, The duration of the radiation signal being completely or partially obscured by a given percentage is less than 20 (1 ±10%) ms, detectors should not generate an alarm state. The duration of alarm should be more than 1 s when alarm state is generated.

2.3. Intrusion detector analog reference target device

The passive infrared detector works by detecting the infrared radiation emitted by the human body: the detector collects the infrared radiation from the outside world and then gathers on the infrared sensor by the Fresnel lens. After the pyroelectric element receives infrared radiation, the temperature will change, then the charge will be released outward, and the alarm will be generated after the detection and processing[7]. The intrusion detector simulates the movement of the human body in the detection coverage area, and the device rotates the detector by using a fixed reference target[8]. The detector is
fixed on the mounting bracket, the stepper motor rotates the bracket at a certain speed by changing gears, and the equivalent human body moves at a uniform speed in the detection coverage area. Moving speed as formula (1) and (2):

\[ V = \frac{2\pi}{\omega} \]  
\[ \omega = \frac{2\pi}{n} \]  

\( \omega \): stepping motor rotation angular velocity  
\( r \): reference target distance from the detector center  
\( n \): step motor rotation speed  

formula (2) the equivalent moving velocity can be calculated by bringing in formula (1). The equivalent speed and distance can be controlled by changing the rotation speed and angle of the stepping motor.  

Also calculated with reference to the target background temperature is as follows:  
The total heat dissipation area of the human body simulator as formula (3):  
\[ A = 0.3 \times (0.235 + 1.50) = 0.52 \text{m}^2 \]  

(3)  
The natural convection heat transfer coefficient of air as formula (4):  
\[ h = 5 \sim 25 \text{ W/(m}^2\text{K)} \]  

(4)  

Maximum temperature difference \( \Delta t = 9 \text{K (ambient temperature 15°C, setting temperature 24°C)} \) Heat dissipation power as formula (5)

\[ Q = h \times A \times \Delta t = 25 \times 0.52 \times 9 = 117 \text{W} \]  

(5)  

If the power removal margin is \( n = 2 \), then the heating power density as formula (6)  
\[ p = n \times Q / A = 450 \text{W/m}^2 \]  

(6)  

The reference target is designed according to the standard size and consists of silicone rubber heater, 6mm thick aluminum plate and insulation material. The silicone rubber heater is mainly composed of Ni-Cr alloy electric heating wire and high temperature insulation layer of silicone rubber. It has the advantages of fast heating, uniform temperature, high thermal efficiency, convenient use and not easy aging. The silicone rubber heater has a good softness and can be in close contact with the heated object, and the heating element can be processed with nickel alloy gold foil, the heating power can reach 1.2 W/cm², and the heating is more uniform. Aluminum sheet has good heat transfer characteristics, so that the heat distribution more evenly up to the standard requirements [9].

The control system adopts PT1000 (precision better than 0.1°C), 16 bit \( \Sigma \Delta \) ADC, intelligent PID control algorithm, modularization design, distributed temperature control, heating power density 1000W/m².

The PID control consists of the proportional unit P, integral unit I and the differential unit D. The relationship between the input e (t) and the output u (t) is as formula (7):  
\[ u(t) = k_p \int e(t) + 1/T_i \frac{e(t)}{t} + T_d \frac{de(t)}{dt} \]  

(7)  

The upper and lower bounds of the integral in the formula are 0 and t respectively so its transfer function is formula (8):  
\[ G(s) = \frac{U(s)}{E(s)} = k_p \left[ 1 + 1/(T_i \times s) + T_d \times s \right] \]  

(8)  

where \( k_p \) is a proportional coefficient, \( T_i \) is an integral time constant, and TD is a differential time constant.

2.4. Anti-headlamp (light) test device  
The anti-headlamp (light) test device is mainly composed of a lamp assembly device, a dark box, a control system, etc. The detector is illuminated by light equivalent to the headlamp through the glass. At the beginning of the test, the halogen lamp is first turned off and the detector is electrified. Wait for detector to enter alert state, then turn on halogen lamp, turn on 2s, break 2s, repeat 5 times, check detector whether alarm state [10]. Lamp assembly is the plane mirror before the installation of vehicle H4 halogen lamp, halogen lamp installation and replacement convenient. The industrial Siemens PLC
is used to control the power supply of lamps and lanterns, which has the advantages of simple operation, stable performance and high control precision.

2.5. Turbulent flow resistance test device
The anti-turbulent flow test device is used to detect the detector should be able to work normally when it is disturbed by hot air flow in the alert state. A 1000W hot air machine with a cross section area of 55mm×180mm is required to be placed at the 1m below the detector and 1m in front of the detector. The flow velocity of the hot air engine is 12° angle toward the detector, the flow velocity from the hot air engine is 2.2m/s ±0.2 m/s, and the flow velocity is 0.7m/s±0.1 m/s when passing through the surface of the detector. Fan power for 5 minutes, the test results should not produce alarm state. The test device is shown in figure 3.

![Figure 3. Anti-turbulent airflow test apparatus diagram.](image)

The device consists of a speed regulating fan,a heating element, an air duct,a wind speed sensor, a temperature sensor and a control system. The speed regulating fan forms the PID closed loop control through the heating element installed in the air pipe, the wind speed sensor, the temperature sensor and the PLC, SCR in the control system, and the flow velocity and temperature are automatically adjusted according to the set value.

2.6. Anti-fluorescence interference test device
The anti-fluorescence interference test device is used to detect the influence of the interference of fluorescent lamp at the prescribed distance from the detector to the alarm state of the detector. The technical requirements are as follows: the lamp tube is placed at 0.5m above the detector and 2.0m ahead. For the detector installed with suction top, the lamp tube should be placed at 1.0m below the detector. The fluorescent lamp should be turned off first, then the detector should be electrified, waiting for the detector to be on alert, then the fluorescent lamp should be turned on for 60s, turned off for 30s,and repeated for 5 times. The detector does not alarm each time the light is on, and then turns the fluorescent lamp 90 degrees again.

The device consists of detector mounting bracket and fluorescent lamp mounting bracket, the height of the support is adjustable, the outer surface is blackened, and the light reflection effect test is reduced. Supports have top mounting and suspension mounting alternative, fluorescent lamp mounting bracket has rotation limit. The on-off of fluorescent lamp power supply is controlled by Siemens PLC in the control box, the control is stable and the on-off time is accurate. The whole control needs only one button to start the test, and the alarm state of the detector triggers the buzzer alarm in the control box.

3. Results
The intrusion detector test device is mainly used to simulate the performance parameters of the intrusion detector. The equipment is divided into five sets of equipment. The test device is mainly composed of an active infrared intrusion detector performance test device, an intrusion detector analog reference target device, an anti-vehicle headlamp (light) test device, an anti-turbulent flow test device,
an anti-fluorescence interference test device. Remote monitoring terminal. The device has the advantages of complete function, simple operation, stable performance, high control precision, accurate collection and good security. In addition, the wireless transmission technology is adopted, and the remote operation can be carried out.

4. Conclusion
The system has passed the Anhui Provincial Department of Science and Technology. The findings of the expert review are as follows:
1. Meet the performance test and anti-jamming test of intrusion detector products, according to the relevant requirements of GB 10408, we can effectively judge whether the key performance indexes of intrusion detector such as false alarm, missed report, interference and so on are qualified.
2. The system can be used for wireless transmission and remote operation to simulate the testing of performance parameters in the operating state of the intrusion detector.
3. The system is divided into 7 equipment, 7 devices do not interfere with each other, can carry on the sample test at the same time, can carry on the single performance test.
4. The system uses PLC automatic control, the function is complete, the operation is simple, the performance is stable, the control precision is high, the collection is accurate, the security is good.

Main technical performance index as follows:
1. Detection category: active infrared, passive infrared, ultrasonic wave, microwave, vibration
2. Rotation angle: 0°-360° adjustable
3. Cylinder velocity: 5 m/s, 10 m/s adjustable
4. Temperature range: 20℃-45℃ adjustable

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