Evaluation on general performance of infrared sensor using a Test-Bed approach

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1. Introduction

An infrared (IR) sensor is a tool most generally used in physical protection systems (PPS) within Korean nuclear power plants (NPP). Consumer manuals are used to help assemble, install and maintain IR sensors. However, the manuals only provide information on the general conditions of a nuclear power plant, and not on the specific characteristics of a plant. In order to provide more specific information, a Test-Bed was constructed and operated [1]. The Test-Bed was an experimental platform used for assessing the performance of the detection and delay functions of a physical protection system (PPS).

This paper discusses the process and results obtained from the performance evaluation of the IR sensor.

2. Status of the Test-Bed

The Test-Bed began operation in July of 2009. (A schematic feature is shown in figure 1.) The dimensions of the system itself are 15 by 15m. Double fences, IR sensors, fence disturbance sensors, CCTV, security lights, and control box were installed. Component specifications are similar to the type used at the real NPP.

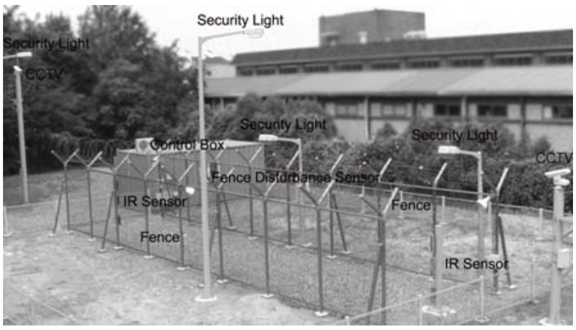

Fig. 1 Test-Bed system outline

3. IR sensor design and Test Methodology

3.1 IR sensor design for testing

An IR sensor detects changes in the signal power of a line-of-sight IR beam between a transmitter and a receiver. The fixed distance between a transmitter and a receiver is 15m. However, their height can be adjusted from 0 to 2m.

The sensor bed surface is composed of gravel. Not only is it an ideal surface material, it is also commonly used at nuclear power plants. An aluminum coated plate is used for changing the reflectance of the surface.

The selected IR sensor model is the most popular one used in Korean plants.

3.2 Test Methodology

The basic performance assessment included: sensor operation checks, alarm margin evaluations, total beam block tests, and slow beam break tests. These assessments were used to expand the understanding operational characteristics and provide accurate information of manuals.

After basic performance tests were conducted, detection probabilities (P_d) were evaluated. The P_d for a sensor is a statistical determination of the probable sensor performance in detecting an intruder [2]. To calculate P_d and the number of trials in a test, equation 1 is generally used.

$$CL = 1 - \sum_{k=0}^{m} \left(\frac{n!}{k!(n-k)!} \right) P_D^{(n-k)} (1-P_D)^k \quad (1)$$

Where,
CL is the confidence level
P_D is the probability of detection
n is the number of trials in a test
m is the number of allowed misses

The tests in this paper, the confidence level (CL) was assumed at 0.95, and the number of trials were more than 100.

4. Test Results

4.1 Sensor operation description

The sensor has four optical lenses in each transmitter and receiver. It was designed to be “AND” gated. As a result, an alarm can only be initiated only when all four stacked beams are simultaneously interrupted. The sensitivity of the sensor automatically increases in bad weather to contend with fog, rain or frost through the programmed auto gain control function. Beam alignment, beam frequency and strength, and response time can be controlled manually.

4.2 Basic operation characteristics

To find basic operation characteristics, alarm margins, total beam blocks, and slow beam block tests were executed.

The alarm margin is defined as the signal margin above the alarm threshold. Measuring the alarm margin was a means of verifying the proper optical alignment; and it can also be useful in identifying marginally operating transmitters or receivers. The alarm margin was determined by measuring the largest possible percentage of blockage of each beam without causing an alarm. Through the test, the evaluated alarm margins were around 17.6 ~ 22.1 dB. These alarm margins are proper values as compared with the results from the Sandia National Lab. in USA [2].

A total beam block and slow beam block is a test in which an IR beam is completely blocked in front of the optical lenses. These tests showed that general detection abilities are more than 95%.

4.3 Detection probability of real intrusion method

A sensor's P_d is meaningless unless it is clearly and specifically defined. For a given sensor installation, a P_d for each possible intrusion method (such as for walking, running, etc.) can be determined based on an intruder's physical characteristics [3]. In this case, normal walking, slow walking, running, crawling, and rolling methods are selected for inclusion in a national DBT.

The speed of an intruder and an evaluated P_d for each intrusion method is listed in table 1. The response time of the IR sensor was fixed at a 0.05 sec; and the number of tests for each method was higher than one hundred. All tests were conducted at sunny days with no wind.

Table 1: Probability of detection for each intrusion method

	Speed of intruder	P_d
Normal walking	1.5 m/sec	Very High
Slow walking	6 Cm/sec	Very High
Running	6 m/sec	Very High
Crawling	-	Very Low
Rolling	-	Very Low

The P_d of an IR sensor for walking and running intrusions were very high. This means that the P_d was higher than 95%. However, a few alarms were raised at the crawling and rolling intrusion because the intruder could be passing without interrupting the four IR beams. These results show that the IR sensors need some kind of device in order to detect someone crawling and rolling. However, this does not mean that current IR sensors cannot be used for actual PPS.

The evaluated P_d of an IR sensor for several intrusion methods will be used to provide data for the SAPE (System Analysis of Physical Protection Effectiveness) program.

5. Further Work

The Test-Bed began operation in July of 2009. The main purpose of the Test-Bed was to obtain domestic data for subsystems and components in a PPS with consideration to different environmental conditions, such as: topography, background noise, climate and weather in Korea.

The remaining tests for IR sensors include the evaluation of nuisance alarms and finding vulnerabilities in the system. After finishing the IR sensor tests, fence disturbance sensors and a CCTV systems will be examined.

REFERENCES

[1] J. H. Lee, "Installation and Operation Guidelines for Test-Bed of Physical Protection System", KINAC, April 2009.

[2] Sandia National Laboratories, "Technology Transfer Manual, Exterior Intrusion Detection", 30. September 1999.

[3] Mary Lynn Garcia, "The Design and Evaluation of Physical Protection Systems", Sandia National Laboratories, 2008.