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Alarm Signal Prioritization of Intrusion Detection Sensors on Nuclear Vital Areas

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Abstract: The nuclear protected area (P.A) inside a limited access area in the nuclear facilities, containing category I or II nuclear material, and/or sabotage targets surrounded by a physical barrier with additional physical protection measures taken to prevent an adversary from achieving an undesirable consequence and to mitigate or minimize the consequences if the adversary initiates such a malicious act. P. A contains nuclear vital areas (V.A) which contain equipment, systems, or devices, or nuclear material, the sabotage of which could directly or indirectly lead to high radiological consequences. The alarm system control panels that are associated with the alarms from security sensors receive alarms each time during the intrusion process. At times, the screens of the alarm system & access control systems have hundreds of alarms as a log of events generated in one hour, The operator and guards who monitoring the facility finds it very difficult to handle and distinguish with the important alarms generated by the alarm system among hundreds of the alarms and log events displayed on the screens. In this Paper, a novel hardware circuit collects the important intrusion detection sensors, such as open door, motion alarm camera, passive infrared, microwave, and glass breakage sensors, in addition to fire detectors, which are distributed in the vital areas. V.A. sensors will be connected to the controller 2085 for controlling the signaling of the alarms received during intrusion and fire cases. In this work, hardware electronic circuits and software embedded programs will be introduced to control the generated alarms received from the intrusion detection sensors located at the vital areas. Software by C Embedded/C Arduino will be used for programming the ESP32-S2 internal chip of the 2085 controller. The program will determine the most important location to control the action of the alarm that has been generated from this region and give the highest priority of their sensors to be displayed immediately at the operator's alarms log events monitors, according to the order of priority. If an alarm is generated from the security and safety sensors, the 2085 controller will arrange the priorities for displaying immediate alarms on the main alarms screen. Live streaming images from the nearest camera located in this area will be displayed. The C Arduino program permits signal receiving from the intrusion detection sensors at the vital areas as a priority level according to the sensors' classification and categorization. The controller system will classify the sensors and determine the highest priority degree and or level of the generated alarms inside the vital areas. Fast action will be taken immediately and easily.

Keywords: Nuclear vital areas priority, Alarm signal categorization, C Embedded/C Arduino, Highly/Low priority alarms, Intrusion detection sensors, CCTV cameras, OD/BMS, Fire sensor, PIR, MW, GB.

1 Introduction

The physical protection measures (including structural, technical and administrative protective measures) taken to prevent an adversary from achieving an undesirable consequence (such as radiological sabotage, or the unauthorized removal of nuclear or other radioactive material in use, storage or transport) and to mitigate or minimize the consequences if the adversary initiates such a malicious act **[1].** Alarm system is one of the auxiliary subsystems of the physical protection system, and it has many ''intrusion detection sensors'' called cluster sensors because their number is distributed in the hundreds inside the facility to cover all areas, such as the protected and the vital areas. The success criterion of the alarm system is the minimum system performance that will allow for the performance of a system safety function under the specific conditions created by an initiating event. So, it should be concentrated on the important alarms, from hundreds of alarms generated from all facility areas, that have been received, and especially the alarms received from the protected and the vital areas promptly for quick decision

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making.

Protected area (P.A): Area inside a limited access area, containing category I or II nuclear material, and/or sabotage targets surrounded by a physical barrier with additional physical protection measures. P. A contains vital areas (V.A) which contain equipment, systems, or devices, or nuclear material, the sabotage of which could directly or indirectly lead to high radiological consequences.

Identification of vital areas is an important step in the process of protecting against sabotage.

Vital area identification (VAI) is the process of identifying the areas in a nuclear facility around which protection will be provided to prevent or reduce the likelihood of sabotage. INFCIRC/225/Rev. 5 (IAEA Nuclear Security Series No. 13 indicates that nuclear material in an amount which if dispersed could lead to high radiological consequences (HRCs) and a minimum set of equipment, systems, or devices needed to prevent HRCs, should be located within one or more vital areas, and be located inside a protected area1. All measures that have been designed into the facility for safety purposes should be taken into account when identifying vital areas **[1].**

2 Alarm Display System

The types of potential threats or activity that are commonly monitored at the vital area are:

Theft, sabotage, flow of employees/visitors, unauthorized entry, and anti-social behavior/vandalism.
The operator/guards need much detail in the picture as

- Monitor a large area
- Detect individuals approaching a building
- Observe the actions of a group
- Recognize known individuals at an entrance
- Obtain images that would enable you (or the police) to identify an unfamiliar individual

The principal task of the operator is to analyze the content of the displayed pictures and take any necessary actions. The designer must decide; the information should be presented to the operator, how the operator communicates with the system, and how the equipment should be arranged at the operator's workstation. The alarm display system should provide the overall status of the site security system, collect sensor status data, and Display sensor messages to the operator (text and map). Figure 1 Illustrates the Independent Alarm Display and Assessment Systems **[5]**

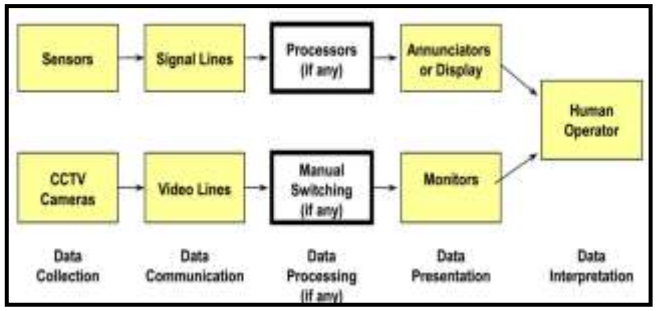

Fig.1: Independent Alarm Display and Assessment.

2.1 Typical Operator Functions [17]

- Start and end assessment of alarms
- Set individual/group of sensors into access
- Open and close doors/gates
- Display system status
- Request procedural instructions
- Assign any CCTV camera to a video monitor
- Start and stop recording on some type of removable media
- Examine system log

2.2 Procedures and Loading

- Operators must be trained to use the system correctly.
- Don't ignore alarms
- Keep Control of the system
- Do not overload operators with extra duties.

Alarm response**:** The signaling of an alarm condition to the CCTV system normally has priority over other inputs. However, irrespective of the degree of automation, the operator should be able to take manual control of the system after an alarm.

2.3 System response times

The following response times should be kept to a minimum:
a) The time elapsing from the generation of an alarm signal and its signaling to the CCTV
b) Control centre switching on receipt of alarm;
c) Camera positioning if pre-set functions on the zoom lens and pan and tilt unit are used.
d) Monitoring equipment start-up time or change from time lapse mode to normal mode
e) Operators' response time if intervention is required. To minimize response times, cameras, monitors, video recorders, etc., should be continuously on, and the system should not generate more information than the operators can effectively manage.

2.4 Surveillance zone determination criteria

A CCTV surveillance installation is designed to monitor events of fundamental importance. These events might be hold up/theft, sabotage/vandalism, hazard, evacuation, etc **[2].** A typical example of a monitoring application is Vital Areas inside the Reactor hot area.

3 Cluster sensors classifications of the security system

In normal electronic circuits which manipulation alarms generated from Security cluster sensors it sends many alarms each time during intrusion of the field of detection, in some cases the screens of alarm systems and access control, has log events hundreds of alarms has been generated in one hour, so it is difficult to handle with the important vital areas alarms between this huge numbers generated alarms. It is necessary to do an inspection seeing on the important places and vital rooms in hot vital areas, such as the fresh fuel storage room, cool coring pumping control rooms, and the spent fuel storage tank in the reactor hall. The time in the case of intrusion attempts in this area becomes very important to take fast action. In this Paper**,** the controller 2085 with an internal ESP32-S2 Chip is used to control the intrusion detection sensors in nuclear facilities and determines that the most important alarms are generated from the protected and vital hot areas. The ESP32-S2 is a single 2.4 GHz, Wi-Fi, and Bluetooth combo chip designed with the TSMC low-power 40 nm technologies; ESP32 has an internal 8 MHz oscillator. The ESP32 contains one or two low-power Xtensa32-bit LX6 microprocessor(s). It is designed to achieve the best power and RF performance, showing robustness, versatility, and reliability in a wide variety of applications and power scenarios. The ESP32-S2 Functional Block Diagram illustrated in Figure2 [**3**]

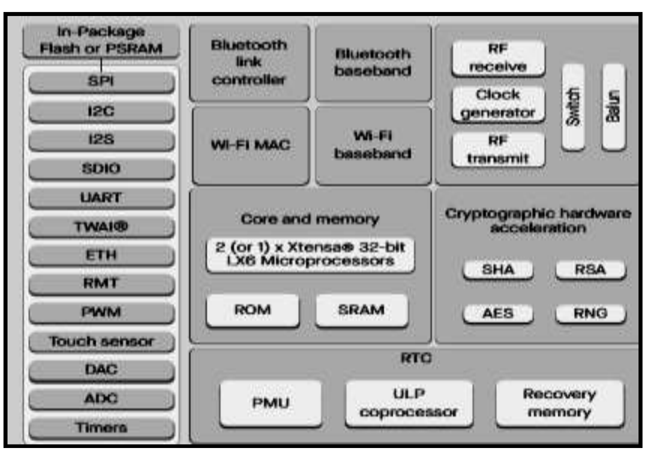

Fig. 2: ESP32-S2 Controller Functional Block Diagram

In this work, a hardware electronic circuit and software software-embedded program will be introduced to control the generated alarms received from the detection sensors of the vital areas. Software by C Embedded/C Arduino programming language will be used for programming the ESP32-S2 internal chip of the 2085 controller. The program will determine the most important place to control the action of the alarm that has been generated from this region and give the highest priority to its important sensors to be displayed immediately at the operator alarm monitors.

If alarm is generated from the intrusion detection sensors and safety sensors, as open door Sensor, camera motion alarm, fire Sensor, passive infrared sensor, microwave sensor, and glass breakage sensor, which are distributed on the vital areas, the controller 2085 will arrange respectively the priority for displaying immediate alarms on the main alarm screens and display live streaming from the nearest camera located at this area on the alarm monitors of the CCTV system. A sound notification from buzzers will be generated inside the CAS Room. A novel hardware electronic circuit will be proposed as an auxiliary circuit connected to the main alarm system. The intrusion detection sensors in the vital area will be connected to this circuit. The software program's function is to arrange the generated alarms as a priority according to sensor classification and categorization.

3.1 Vital Area Priority and Classifications

The priority of the ESP32 Control System will be classifying the generated alarms from the intrusion sensors into two types: Highly/Low Priority Alarms (AL2 & AL1)

- **AL2:Highly Priority Alarms** will be displayed immediately on the Alarm monitoring control unit, with live streaming camera video displayed on the main alarm monitors on the operator CAS room, where AL is the alarm level.
- **AL1: Low Priority Alarms** will be displayed on the main Pc server unit and alarm system monitor. The electronic control system will classify the alarms:

3.1.1 Generated Alarms Categorizations

The Terrorist or adversary will take place for attacking the nuclear facility and enter the hot vital area, in this intrusion highest cases, the intrusion detection senor will generates an alarms and send it to the alarm system control panel, the ESP32 control system will arranges the action as: The first step action when the terrorist try opening the door of the vital area, via open door sensor or balanced magnetic switch, after that he goes through the inner vital area.

CCTV camera motion sensor will record his motion and displayed a live video to CAS room, these two alarms will be selected by ESP32 Control System immediately and displayed on the main alarms monitors for security guards and operators, if there are any fire alarms comes from heat/smoke sensors inside this vital area the ESP32 Control System will give it the highest priority and will display this alarm immediately at CAS room. The operator/guards at the CAS room supervise at all times the types of potential threats or activity that are commonly monitored at the vital area and assessment of generated alarms according to the system alarm priority and classes **[**4**].**

The operator/guards must examine the alarm system logs and display system statuses, which display intrusion detection sensors in colors:

- RED means: Alarm, and there is are intrusion at the vital area
- Green means: Normal and no threat
- Yellow means: the system has trouble or/fault and needs maintenance **[**7**]**

The ESP32 programming System arranges received alarms for the operator/guards as a priority level and classifies them into the following categorizations and priority levels.

- **Category 1:** AL2 Level will be **High Priority,** and
- **Category 2:** AL1 Level will be **Low Priority**

The operator/guards will receive the high-rated alarms (Category 1) first as a high priority, and examine them among the hundreds of alarms generated by the alarm system; this selection process is done by the ESP32 Control System. The ESP32controller will then resend the low-rated alarms (Category 2) as a low priority to the operator/guards for monitoring and processing them. In the two alarm cases, the operator/guards in the CAS Room will handle the generated alarms and examine them.

3.1.2 Hardware Classification for Intrusion Detection Sensors

A novel hardware circuit collects the important intrusion security sensors and fire safety sensors in a vital area and connects them to the controller 2085 for controlling the signaling of the alarms received during intrusion and fire cases. During the motion of the terrorist/or adversary inside the nuclear facility vital areas, the intrusion detection sensors inside the vital area such as the passive infrared (PIR), microwave (MW), Glass breakage sensors (GB), and open door sensor (OD or /BMS) will pick up the disturbance action on the flux or the pattern at the sensors field of operation and alarm signal will be generated and transmitted immediately to the CAS Room. In this work, the data sheets of the security sensors, OD/BMS, CCTV Camera, Smoke fire detector, PIR, MW, and GB, were used for connecting the important/high-priority sensors, which are located on V.A., to the ESP32 control, processor 2085, main alarm panel [20,21,22,23].

Figures 3, 4, and 5 show the sensor's shape, working phenomena, and the terminal of the output signal has been connected to the hardware circuit of the ESP32 controller.

The programming of the processor 2085 by C Embedded/C Arduino will permit arranging the alarm action occurrence to display on monitors in sequence. The security guards will receive these alarms as a priority according to the importance and categorization of the sensor. The highest priority will be first for the open door OD or /BMS, Fire smoke detector CCTV Camera motion alarm, The lowest priority will be PIR, MW, and GB sensors respectively, if terrorist try to break the glass barriers or windows this will be the third generated alarm from GB Sensor and its category is the last priority. Also, the fire smoke detector will be the highest priority in all cases. The detection sensors will be categorized and classified as follows.

CATEGORY 1: AL2 Level **(High Priority)**, the received alarms from the nuclear V.A sensors have been ordered, respectively, for a sequence displaying on the main alarm screen, with a priority of alarm receiving

1st: OD/BMS (Open Door Sensor or/and Balanced Magnetic Switch)
2nd: CCTV Camera Live Streaming on the Main Alarms Monitors
3rd: Fire Detector (Smoke/Heat)

The ESP32 Control System, after receiving AL2, considers it a High Priority Level, and displays it immediately at CAS on the main alarm screen with a buzzer sound alarm.

Figures 3a, b, c illustrate the sensor types of category AL2 (High priority)

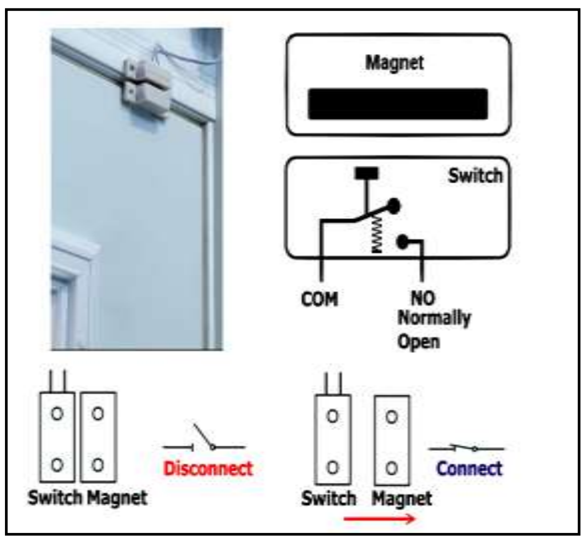

Fig3a. Open Door BMS CAT1 High Priority

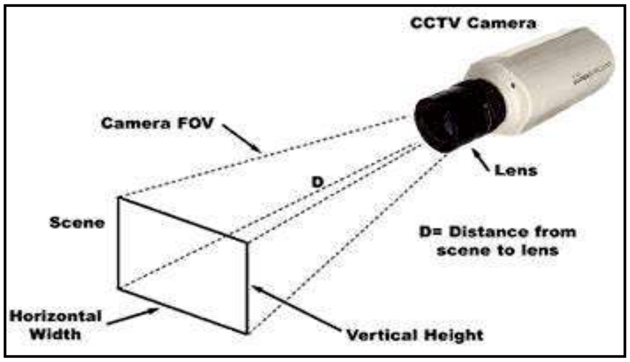

Fig 3b. Surveillance Camera CAT1 High Priority.

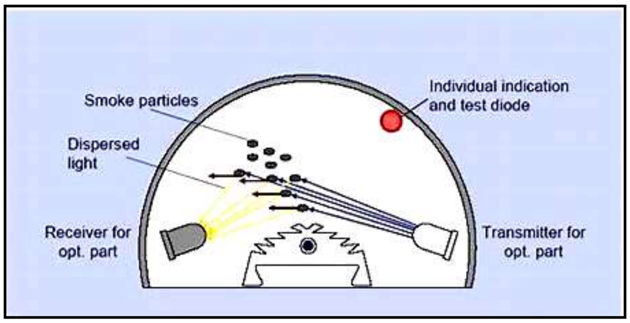

Fig 3c. Fire Smoke Detector CAT1 High Priority

The second or/low-level priority of the generated alarms from the intrusion detection and fire sensors inside the nuclear vital area will be categorized as:

CATEGORY 2: AL1 Level **(Low Priority),** the received alarms from the V.A sensors have been ordered respectively for a sequence displaying on the main alarm screen, as a priority of the alarm receiving (after receiving CATEGORY 1: AL2 Level (High Priority)

4th: PIR: Passive infrared sensor

5th: MW: Microwave sensor

6th: GB: Glass breakage sensor

Figures 4a, b, c illustrate the sensor types of category AL1 (Low priority).

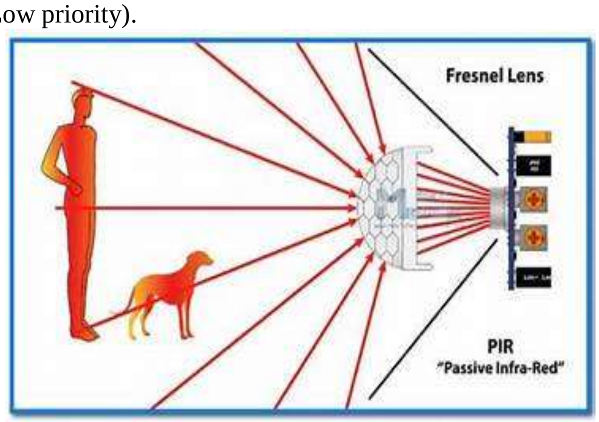

Fig 4a. Passive infrared sensor CAT2 Low Priority.

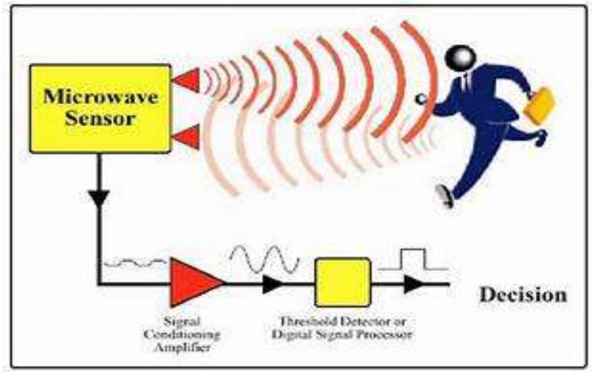

Fig 4b. Microwave sensor CAT2 Low Priority .

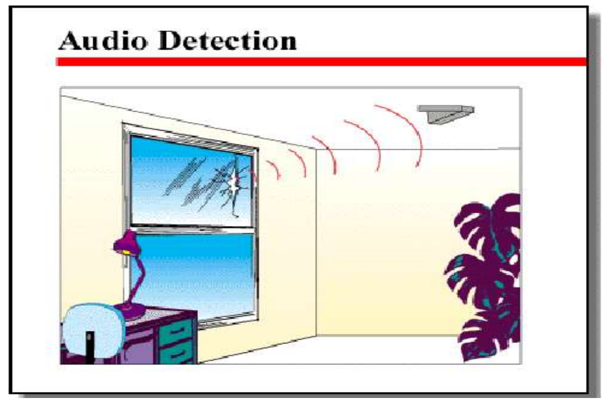

Fig 4c: Glass Breakage Sensor.

Figure 5 shows the electronic circuit design, which includes the connection of the intrusion detection sensor types to the ESP32 Control System supported with WI-FI, Bluetooth, and a PC server. All generated alarms are displayed immediately on the main alarm screen.

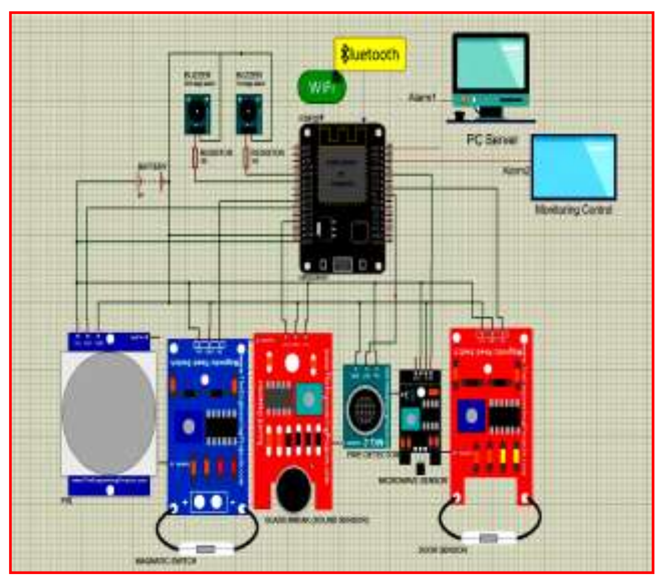

Fig. 5: ESP32 Control System Electronic Circuits Design.

4 C Arduino Software and Vital Area Sensors Classification

The ESP32 programming System arranges the received alarms from the alarm system and the signals transmitted from the intrusion detection sensors: OD/BMS, Alarm Motion Camera, Fire Detector, PIR, MW, and GB. The software program classified it as a priority; high priority and Low Priority, and displays the high priority alarms first on the main screen at the front of operators/Guards in the CAS room to take immediate action. By using C Embedded/C Arduino programming language **[19],** the software program will arrange the priority and categorization of the alarms that have been generated according to the previous classifications. The created C Arduino software program is displayed below.

C ARDUINO PPS CLASSIFICATIONS PROGRAM

```
#include <WiFi.h>
const char* ssid = "ESP32 LAN";  // Network ID Network
Name
const char* password = "314159265359"; // Network
Password
const char* serverIP = "192.168.1.1";  // PC's IP Server IP
Address
const int serverPort = 8080; // Network port
Communication Port
WiFiClient client; // Network Call
#define CCTV 2
#define PIR 27 // D27 Passive Infrared Sensor
#define GB 14 // D14 Glass Breakage Sensor
#define MW 4 // D4   Microwave Sensor
#define OD 18 // D18 Open Door Sensor
#define FIR 5 // D5 Fire Detection Sensor Heat/Smoke
#define BMS 26 // D26 Balanced Magnetic Switch
Sensor
#define BTN 7 // Reset button Reset System Working
#define AL1 32 // Low Level Alarm
#define AL2 33 // High Level Alarm
const int PCCTV = 1;
const int PFIR = 2;
const int PPIR = 3;
const int PGB = 4;
const int PMW = 5;
const int POD = 6;
const int PBMS = 7;
int alt = 0; // alarm reference
void setup( ) {Serial.begin(9600);
WiFi.begin(ssid, password); while (WiFi.status() !=
WL_CONNECTED) { //Connecting WIFI and Check
 delay(1000);
 Serial.println("Connecting to WiFi...");
 }
 Serial.println("Connected to WiFi");
 if (client.connect(serverIP, serverPort)) { //Connecting
Server and Check
Serial.println(  "Connected to server");
} else {Serial.println("Connection to server failed");
}
   pinMode(CCTV, INPUT);
   pinMode(PIR, INPUT);
   pinMode(GB, INPUT);
   pinMode(MW, INPUT);
   pinMode(OD, INPUT);
   pinMode(BMS, INPUT);
   pinMode(FIR, INPUT);
   pinMode(BTN, INPUT);
   pinMode(AL1, OUTPUT);
   pinMode(AL2, OUTPUT);
}
}
void loop() {
   if (alt == 0) {
      if (digitalRead(BMS) == HIGH) {
         trigg(PBMS);
         alt = 1;
} else if (digitalRead(OD) == HIGH) {
         trigg(POD);
         alt = 1;
} else if (digitalRead(PIR) == HIGH) {
         trigg(PPIR);
         alt = 1;
} else if (digitalRead(MW) == HIGH) {
         trigg(PMW);
         alt = 1;
} else if (digitalRead(GB) == HIGH) {
         trigg(PGB);
         alt = 1;
}
}
delay(100);
   if (digitalRead(CCTV) == HIGH) {
      trigg(PCCTV);
      trigg(PFIR);
}
   delay(100);
   if (digitalRead(BTN) == HIGH){
     alt = 0;
     delay(500);
}
}
void trigg(int priority) {
   String message;  switch(priority) {
      case PCCTV:
         message = "Camera alarm";
         Serial.println(message);
         digitalWrite(AL1, HIGH);
         digitalWrite(AL2, HIGH);
         break;
      case PFIR:
         message = "Fire detected";
         Serial.println(message);
         digitalWrite(AL1, HIGH);
```

```
        digitalWrite(AL2, HIGH);
        break;
      case PPIR:
        message = "Motion detected";
        Serial.println(message);
        digitalWrite(AL1, HIGH);
        break;
      case PGB:
        message = "Glass break detected";
        Serial.println(message);
        digitalWrite(AL1, HIGH);
        break;
      case PMW:
        message = "Microwave on";
        Serial.println(message);
        digitalWrite(AL2, HIGH);
        break;
      case POD:
        message = "Door opened";
        Serial.println(message);
        digitalWrite(AL2, HIGH);
        break;
case PBMS:
        message = "Balance magnetic switch alarm";
        Serial.println(message);
        digitalWrite(AL2, HIGH);
        break;
      default:
        return;}
    if (client.connected()) {
      client.println(message);
      Serial.println("server's message: " + message); }
else {
      Serial.println("Not connected to server");  }}
```

5 Output Results

After programming and running the new circuits included the intrusion detection sensors in the vital area, the plotting diagram of the ESP32-S2 controller 2085 response of V.A sensor categorization and priority is shown in Figure 4.

ESP32-S2 Controller time responses (Seconds) are shown in Table 1. The figure explain that the system is picked up the category1 high priority (OD/BMS, FIREDECT, CCTV CAM), first after 1 second, and follows the others cat1 high priority sensors (respectively during 2 seconds, and displayed them to the front alarms screen on the CAS room to the operator/guards the system response begin again to pick up the category 2 low priority (PIR, MW, GB) after 2.5 seconds- to-3.5 seconds and continue sending these alarms to the alarms screen at the CAS room. Table 1 shows the ESP32-S2 Controller time response with the sensor priority. The ESP32-S2 Controller take the minimum response time, 1second, for the open door sensor (OD/BMS) for displayed this alarm on the main alarm screens, and take the maximum time response, 12 seconds, for the glass breakage sensor for displaying this alarm on the main alarm screens, the sequence fort displaying these alarms are: OD or /BMS, fire smoke detector, CCTV Camera motion alarm, PIR, MW and GB sensors respectively.

Table 1: The ESP32-S2 Controller time response with the sensor priority.

Category/Priority	ESP32-S2 Controller time response (Seconds)					
Level/Sensor	OD/BMS	FIREDCT	CCTVCAM	PIR	MW	GB
Cat1 High priority	1	1.5	4	5	6	7
Cat1 High priority	1.5	2	5	6	7	8
Cat1 High priority	2	3	6	7	8	9
Cat2 Low priority	2.5	4	7	8	9	10
Cat2 Low priority	3	5	8	9	10	11
Cat2 Low priority	3.5	6	9	10	11	12

Figure 4 shows the plotting diagram of the ESP32-S2 controller response of the V.A. sensors category and priority.

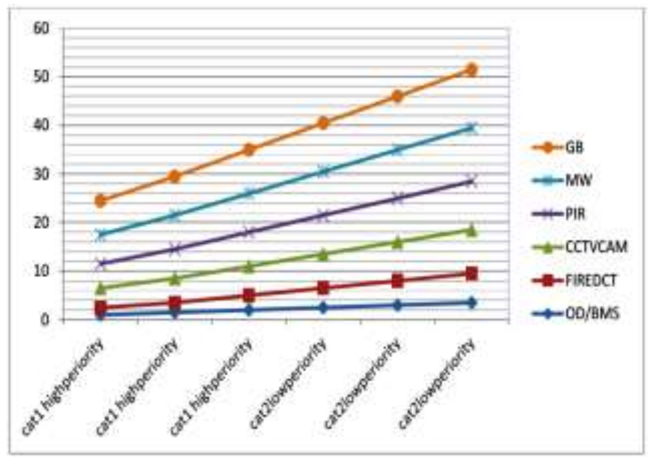

Fig.4: ESP32-S2 controller response to V.A sensors categorization and priority.

6 Conclusions

The physical protection system (PPS) is designed to prevent radiological sabotage and/or theft of nuclear materials present within the nuclear facility, especially nuclear vital areas (V.A.), which contain equipment, systems, or devices, or nuclear material, the sabotage of which could directly or indirectly lead to high radiological consequences. The alarm system control panels received hundreds of alarms in one hour. The operator and guards who monitor the facility find it very difficult to handle and distinguish the important alarms generated by the alarm system among hundreds of alarms and log events displayed on the screens. In this Paper**,** a novel hardware circuit collects the important intrusion security sensors and fire safety sensors in the nuclear vital areas and connects them to the controller 2085 for controlling the signaling of the alarms received during intrusion and fire cases. The system classified these sensors as the highest priority degree and or level of the generated alarms inside the nuclear vital areas. C Embedded/C

Arduino programming language used for programming the control microprocessor 2085 ESP32**.** The created software program and hardware circuit will determine the most important place to control the action of the alarm that has been generated from this region, and classify the degree and level. The ESP32-S2 Controller take the minimum response time, 1second, for the open door sensor (OD/BMS) for displayed this alarm on the main alarm screens, and take the maximum time response, 12 seconds, for the glass breakage sensor for displaying this alarm on the main alarm screens, the sequence fort displaying these alarms are: OD or /BMS, fire smoke detector, CCTV Camera motion alarm, PIR, MW and GB sensors respectively. The system gives the highest priority to its important sensors' alarm signals to be displayed immediately at the operator's alarms log events monitors, according to the order of priority, and fast action will be taken immediately.

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