AN EFFICIENT MONITORING SYSTEM FOR INDUSTRIAL AUTOMATION USING ZIGBEE TECHNIQUE

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ABSTRACT

This paper presents a proposal for a wireless Zigbee-based controlling and monitoring system for industrial automation system. The benefit of this work is to replace the wires connected between the devices and the controlling part for economical but more secure data communication because wired communication costs more or is impossible due to various physical conditions. A module of the proposed system has been designed and implemented. It is composed of several components such as Arduino, fire sensor, gas sensor, light sensor, motion sensor, door sensor, 3 LED, 2 micro servos, and 2 XBee modules, all working on ZigBee Technology. The control system has been programmed and a user interface is created on the PC using the LABVIEW environment for the visualization of applications. The wireless monitoring system for industrial automation based on Zigbee protocol is achieved and tested successfully. The results showed that the system developed an efficient mechanism to control and monitor the basic parameters for any industrial automation system with improved reliability, low power consumption, and cost at exceptional capability and highly flexible configuration.

Keywords: industrial automation, Zigbee protocol, wireless, controlling and monitoring system, sensor.

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1. INTRODUCTION

With the increase in the number of consumers, factories needed to increase their production, considering the cost of production, and improving its quality. Therefore, factories were automated to reduce the number of workers in factories, which reduces the number of human errors caused by negligence as well as reduced salaries and health insurance, factories also became more able to work for more hours because of dependence on automation. Industrial automation mostly depends on power systems that require distance-controlled and regulated systems. Mostly, voltage and current-equipped parameters along with power and energy management systems form the industrial scenario for automations [1].

There are two main types of automation. First, is the most common type of automation using wires. However, it has many drawbacks such as the large number of cables needed difficulty in changing the design of the used cables to improve connectivity in the future or the development of the industry, cost of maintenance, and need long time. Second, is the wireless automation that is using a Wi-Fi network or Bluetooth? Yet, both wireless systems cannot connect many devices and their power consumption is very high. Therefore, to reduce the cost and connect many devices, the ZigBee technique can be applied in controlling and monitoring an industrial automation system due to its various benefits such as reliability, low power consuming profile, good capability, better flexibility, and low cost. Due to the low complexity, ZigBee devices normally have lower costs than their wired counterparts. Unlike analogous wireless technologies such as Bluetooth, ZigBee possesses multichip capabilities, which allow for the extension of the wireless network coverage [2].

Current industrial automation systems need pre-planning requirements, higher costs of installation and maintenance of the wired network, and difficulty in connectors troubleshooting [3]. Less flexible infrastructure due to fixed connections. On the other side, disadvantages of short-range connection and poor data security of Bluetooth network. In addition to the high power consumption of Wi-Fi [4]. To solve the above-mentioned problems, the implemented system is flexible, reduces wire installation, and maintenance costs, is reliable, and can be easily implemented.

In [5], home automation household appliances and residential house features like gates and curtains are controlled automatically or semi-automatically. The home automation system uses IR (Infrared Radiation) remote, Bluetooth, and GSM (Global System for Mobile) to control AC appliances using Android apps. The system is useful when people are away from home, and they may forget to switch off the AC appliances which causes a waste of energy. Factory automation applications operating on wireless communication systems were presented in [6]. However, using such a system may exceed the coverage area of a single base station, requiring the capability of device movement between multiple base stations. In [7], the ZigBee method was used to design a fire monitoring system including a data collecting module, WIFI (Wireless Fidelity) transmitting module, and remote monitoring module. The system adopted the idea of ZigBee wireless sensor network nodes, which collect detected signals and locate the fire location. Then ZigBee network transforms into a Wi-Fi network, by which signals are transmitted to the monitoring center. An online monitoring system was designed [8] to early warning about environmental quality in the manufacturing industry.

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The system can provide real-time and accurate data for staff, stakeholders, and control centers to monitor factory air quality at working workplace. By uploading all collected data on the internet, the environmental condition can be monitored in real-time by users. A feedback system was realized to detect the sensor's status. In [9], an Embedded system was applied for the development of a smart residential fire detection and extinguishing system. The capability of wireless communication was integrated into various fire sensors and alarm devices. The system activates the fire alarm to warn occupants and executes emergency and rescue calls to remote residents and fire-fighting facilities. The location of the system activates the fire alarm to warn occupants and executes emergency and rescue calls to remote residents and fire-fighting facilities.

A home automation and security system using Android ADK (Accessory Development Kit) was presented in [10]. The designed system was based on a standalone embedded system board Android ADK at home. Home appliances were connected to ADK, and communication was established between the ADK and Android mobile devices. In the system, the home appliances were connected to the input/output ports of the embedded system board, and their status was passed to the ADK. The work proposed in [11] was to monitor and control the PLC based system using wireless topology based on a ZigBee and SCADA (Supervisory Control and Data Acquisition) technology to develop a wireless automation system. In [3], a smart home automation system based on Arduino (microcontroller) and Android apps was presented. In the system, Bluetooth chips have been used with Arduino, thus eliminating the use of personal computers (PC). Also, several devices such as lights, and DC (Direct Current) servomotors have been incorporated into the designed system to demonstrate the feasibility, reliability, and quick operation of the proposed system. The designed system has been tested and it is seen as capable of running successfully and performing the desired operations, such as switching functionalities, position control of the servomotor, speed control of the DC motor, and light intensity control (Via Voltage Regulation). However, the main drawback of the Bluetooth control system is that the operating range is low, and it cannot be controlled from a long way. The proposed intelligent lighting system in [12] was reported for energy optimization by using the integration of sensors and controllers. The main control was designed using various sensors to collect the relevant data for the management and maintenance of the lamp. Furthermore, ZigBee and GSM wireless technologies were used for wireless communication. Hence, in this work, an inexpensive and efficient controlling and monitoring system for industrial automation based on Zigbee technology is designed, implemented, and tested. The proposed system can control and monitor the basic parameters for any industrial automation system with better reliability and excellent flexibility at a low cost.

2. METHODOLOGY

The working principal flowchart of the proposed wireless controlling and monitoring system based on Zigbee technology is shown in Figure-1. The block diagram of the proposed system is displayed in Figure-2. It consists of several main components such as two XBee modules, a relay, PC, Arduino, fire sensor, gas sensor, light sensor, motion sensor, door sensor, 3 LED, 2 micro servos, all working by using ZigBee Technology. An Arduino is an open-source platform [13] used to simply combine programmable electronics circuits like in [14]–[17]. As shown in Figure-1, the working principle of the proposed system can be divided into three different ways according to the working time mode. Consequently, during the working time mode, the operating industry devices are used. While, during the working nighttime mode, the security sensors network is ON. Therefore, there are no activities within the industry. However, the emergency sensors are working at all times. The working principle of the proposed wireless systems is as follows:

a. Working Time Mode

The following steps are the working principle of the proposed monitoring system during working time mode:

a) Start this mode via the "work mode" button in the LabVIEW interface.
b) Turn on the LED lights based on the command given in the LabVIEW interface.
c) Detect the illumination status by the light sensor and display it at the LabVIEW interface.
d) Receive commands to the servo motor and execute them according to the angle specified in the LabView interface, and the angle is shown in the LabVIEW interface.

b. Out-Of-Work Mode

In out-of-work mode, safety sensors are working during that time to protect the industry place from being stolen and intrusion in the absence of employees. It works as follows:

a) Scan the motion within the working area and the movement is detected by a PIR motion sensor.
b) If there is movement, the PIR sensor sends a signal to turn on the buzzer alarm, and the alert is displayed in the LabVIEW interface.
c) If the door is opened in the working area, the magnetic door sensor sends a signal. At the same time, the alarm works, and a warning is displayed at the LabVIEW interface.

c. All Time Mode

In all-time mode, the emergency system works continuously to protect the industrial area and its employees as follows:

a) Scan the area continually with the flame sensor. In case an alarm fire is activated, a signal will be sent to the system and displayed in the LabVIEW interface.

b) Detect dangerous gases frequently by the MQ2 gas sensor and in the case of one of those gases the alarm works, it will be displayed in the LabVIEW interface.

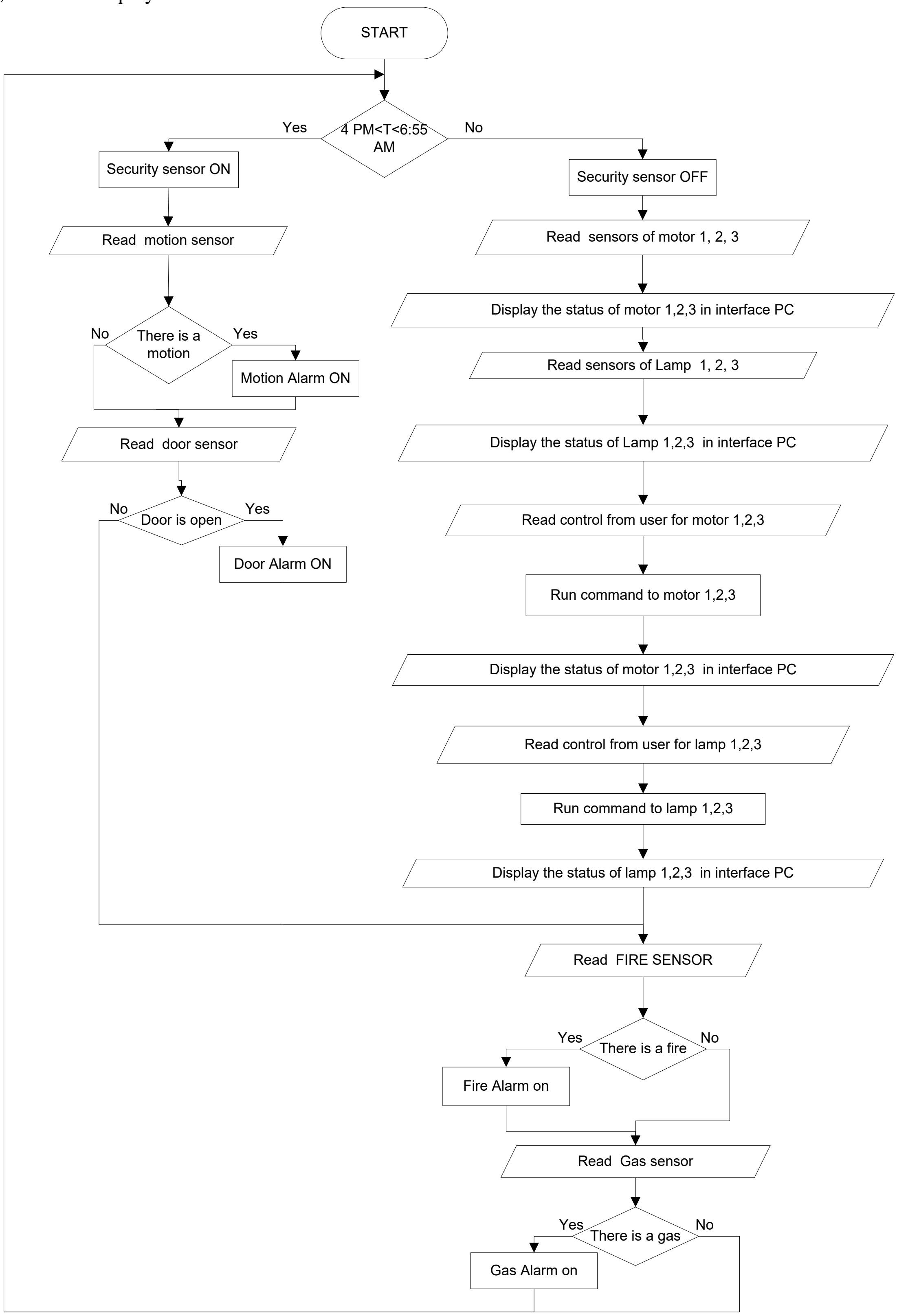

Figure-1. Working principal flowchart of the proposed monitoring system.

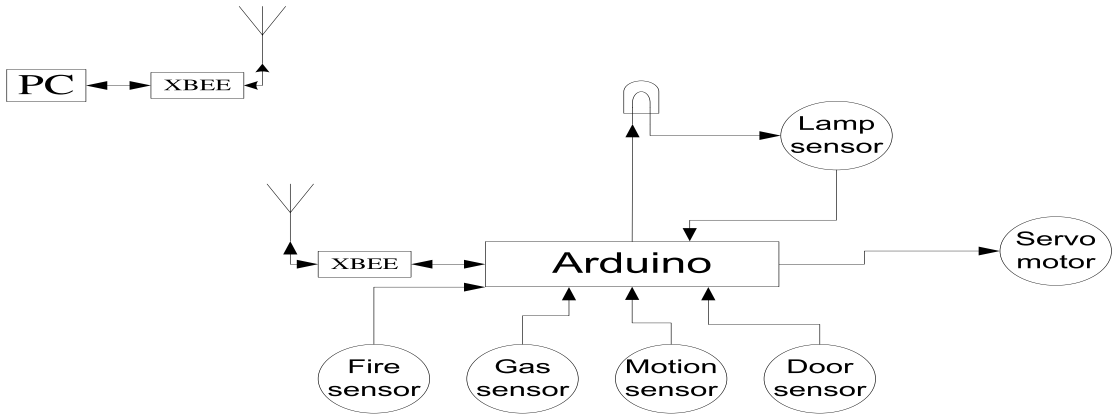

Figure-2. Block diagram of the proposed monitoring system.

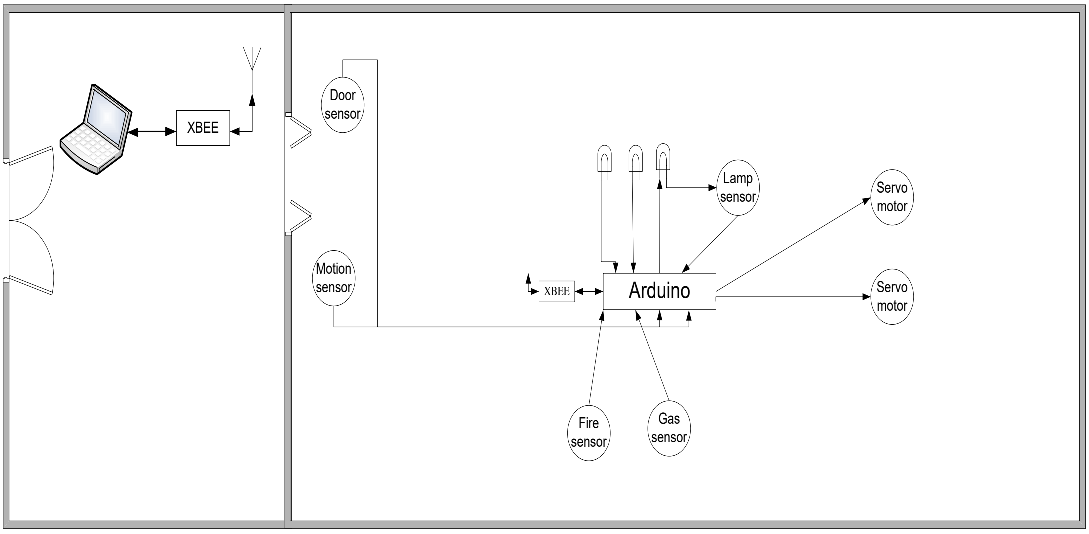

Figure-3. 2D plan of the proposed monitoring system.

A two-dimensional (2D) plan of the designed wireless system is presented in Figure-3. As shown in the figure, the proposed monitoring system is composed of the following components: Arduino, PC, fire sensor, gas sensor, door sensor, motion sensor, lamp sensor, motor sensor, two servo motors, LED, and two XBee modules.

3. RESULTS AND DISCUSSIONS

In this section, the proposed wireless Zigbee-based controlling and monitoring system for industrial automation system is implemented, tested, and verified. The experimental results show that the proposed system can be used to control and monitor the basic parameters for any industrial automation system with better reliability and excellent flexibility at a low cost. Moreover, all the results of the construction and operation processes of the proposed system are provided. Also, a photograph of the component's connection is given as well.

a. System Setup

- Add LabVIEW interface for Arduino from NI Package Manager to use LabVIEW blocks for Arduino programming.
- Determine the type of connection to Arduino with LabVIEW wirelessly via XBee.
- Create a work mode (OK) button to determine the mode of work.
- Built the front panel to complete the work as shown in Figure-4(a), where the LabVIEW block diagram is presented in Figure-4(b).

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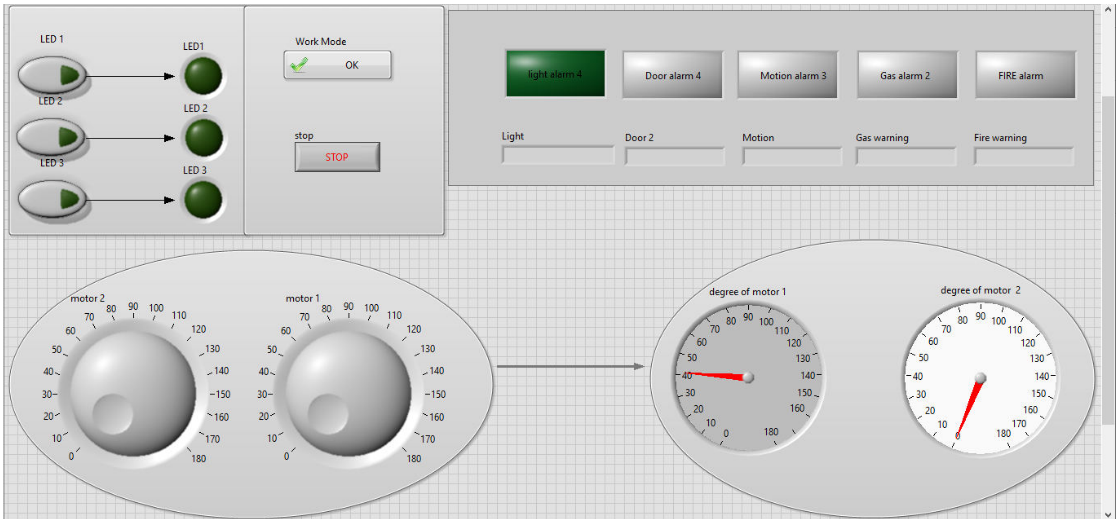
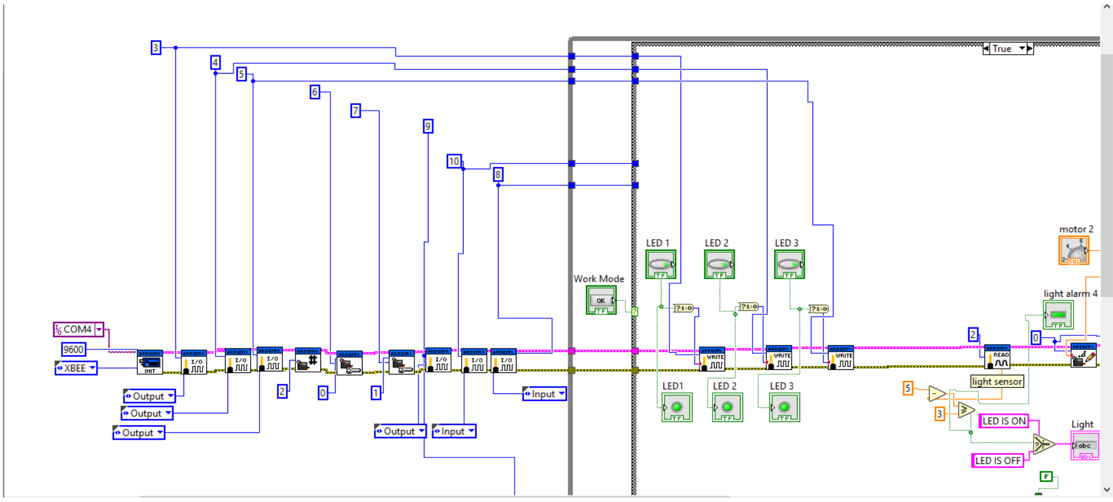


(a)



(b)

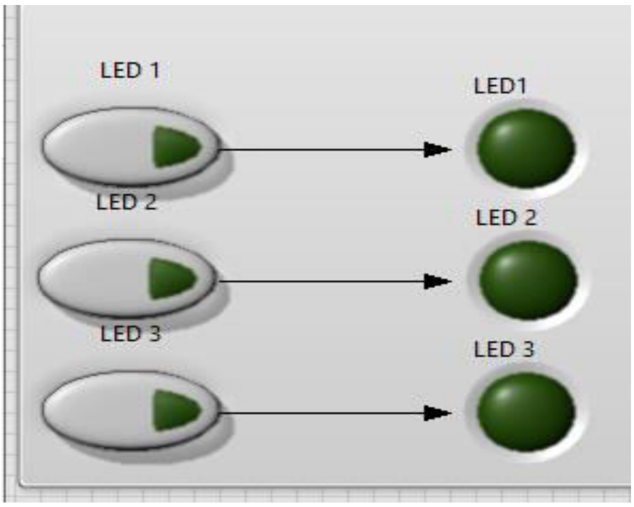
Figure-4. LabView interface of the proposed system.

b. Working Time Mode

- Generate the working time mode by clicking on the (OK) button to start this mode as shown in Figure-5(a).

(a)

- The implemented LED push buttons are used to control LEDs and (Round LED) indicator is to show its status as displayed in Figure-5(b).



(b)

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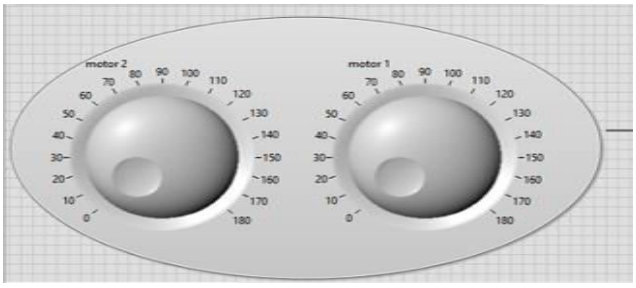
- Create a frame color box and a horizontal progress bar for the light sensor to check its condition and to detect if lights are working or not as demonstrated in Figure-5(c).

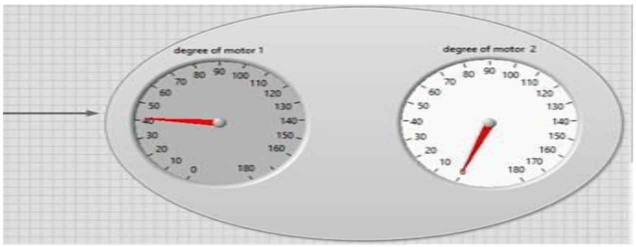
(c)

- Create servo motor knobs to control the angle of the motor as shown in Figure-5(d).



(d)

- Make a gauge to display the servo motor angle as indicated in Figure-5(e).



(e)

Figure-5. LabView interface for working time mode.

c. Out-Of-Work Mode

Build a frame color box and create a horizontal progress bar for security sensors (PIR motion sensor and door sensor) as revealed in Figure-6 to show any alert in case of a breakthrough industry area.

Figure-6. LabView interface for out-of-work mode.

d. All Time Mode

Generate frame color box and horizontal progress bar as well in the front panel of LabVIEW for emergency sensors (flame sensor and gas sensor) as demonstrated in Figure-7 to show any alert in case of fire or leak gases through the industry area.

Figure-7. LabView interface for all time mode.

e. System Implementation

Figure-8 shows a photograph of the proposed system implementation. In this system, the sensors network, LEDs, and servo motors with the Arduino and XBee (in device) send and receive data from and to another XBee (coordinator) that relates to the PC as shown in Figure-8(b).

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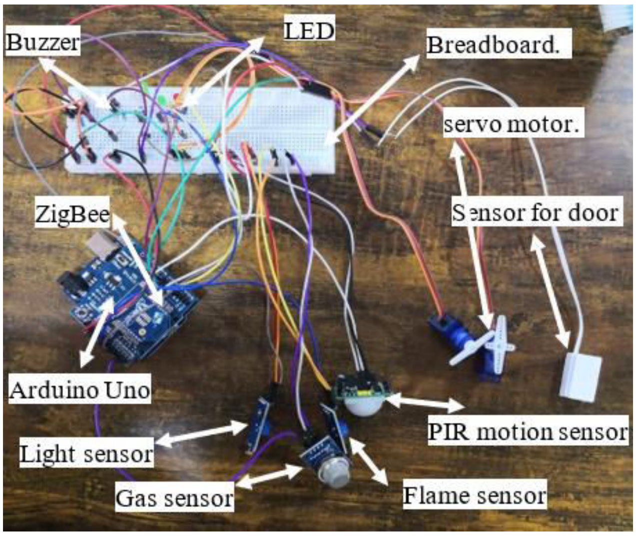
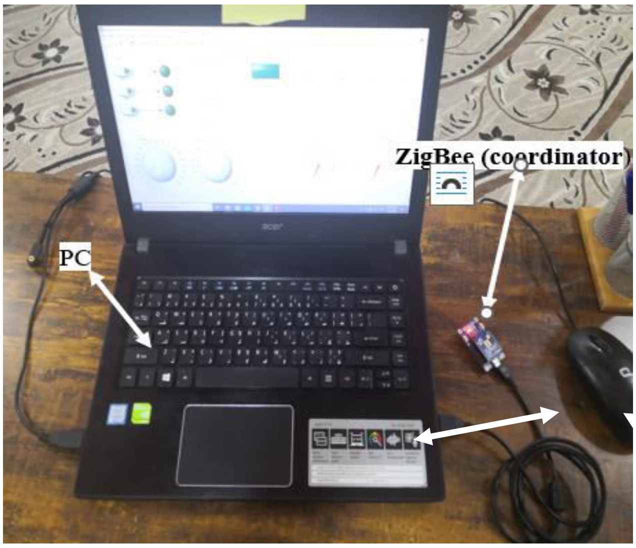


(a)



(b)

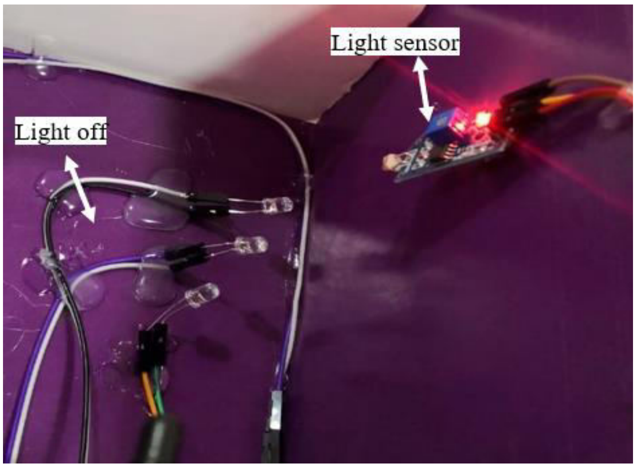
Figure-8. A photograph of the proposed system.

The proposed wireless monitoring system enhances the viewpoint of developing, transferring, and reassessing scientific knowledge of ZigBee technology monitoring systems for industrial automation made for real-time applications. Therefore, quality and reliability are required. The experiments were performed to evaluate the system's reliability. The test area consists of a small model that simulates a real industrial facility. It is observable that the XBee module sent and received the data correctly. It connects the PC to the Arduino board, and the transmissions and reception operations between the two parties by the XBee module were excellent.

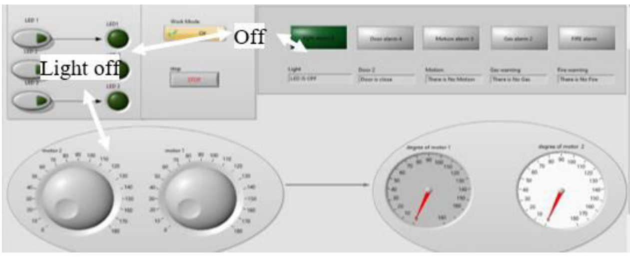
f. Working Mode Test Results

- The LED lights worked well when stopped as in Case 1 and started as in Case 2. The light sensor detected the presence of light as shown in Figure-9(a)-(d).
- The servo motors worked properly when an angle was specified in the control front panel as presented in Figure-9(e)-(g). The motor operating angle is displayed in the LabVIEW interface as shown in Figure-9(f)-(h).

Case 1 (when light is OFF):



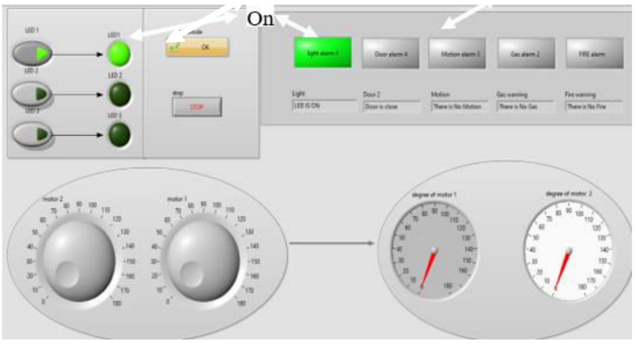
(a)



(b)

Case 2 (when light is ON):

(c)



(d)

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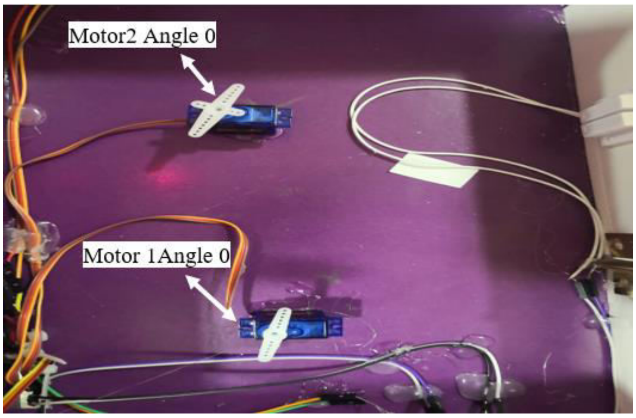
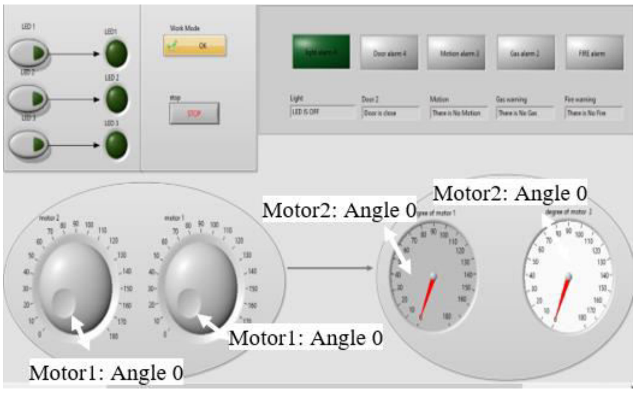
Case1 (angle of two servo is zero):

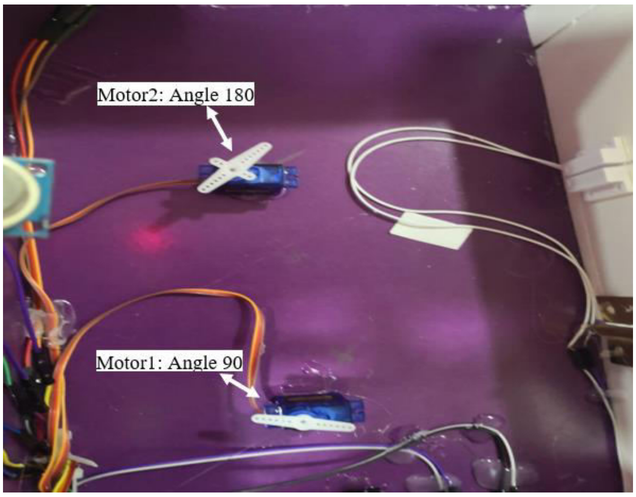


(e)

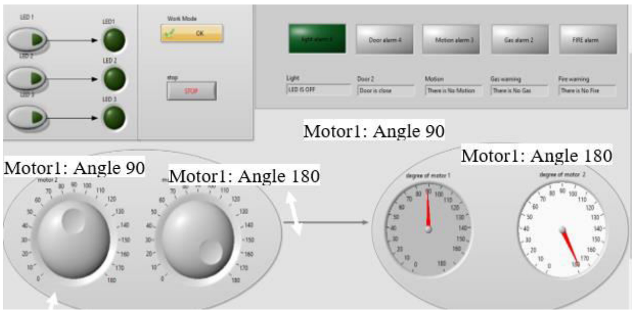


(f)

Case2 (angle of motor 1 is 90 and motor 2 is 180):



(g)

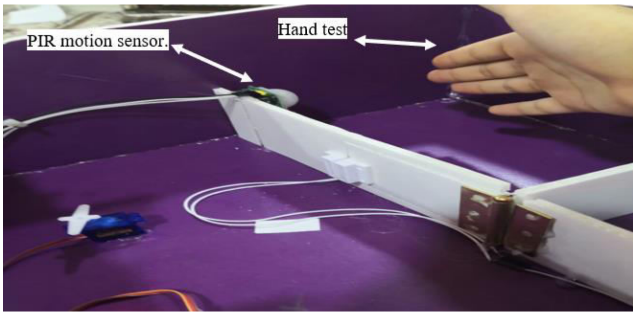


(h)

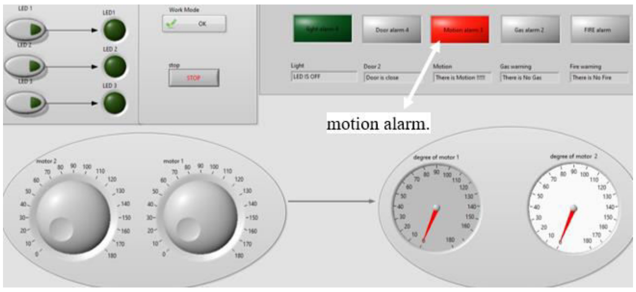
Figure-9. Working time mode test results.

g. Out-Of-Work Mode Test Results

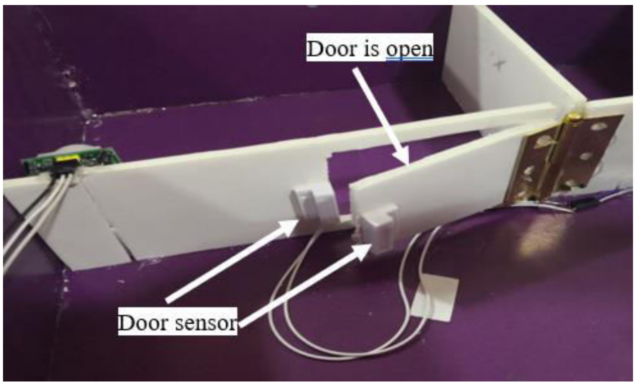
- The PIR motion sensor detects any movement when it is tested by hand as shown in Figure-10(a). The alert is displayed in the LabVIEW interface as presented in Figure-10(b).
- In the door sensor test experiment, if any door is open as shown in Figure-10(c) (out of work mode) the buzzer is on and the alarm is displayed at the LabVIEW interface as demonstrated in Figure-10(d).



(a)



(b)



(c)

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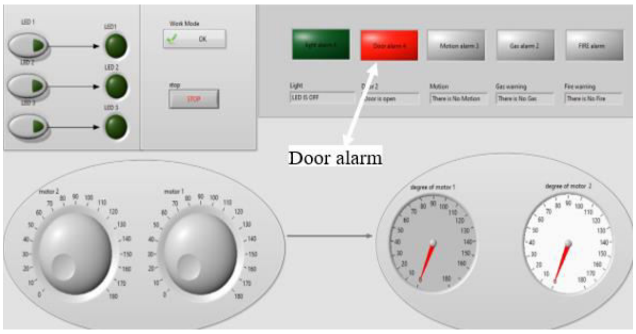
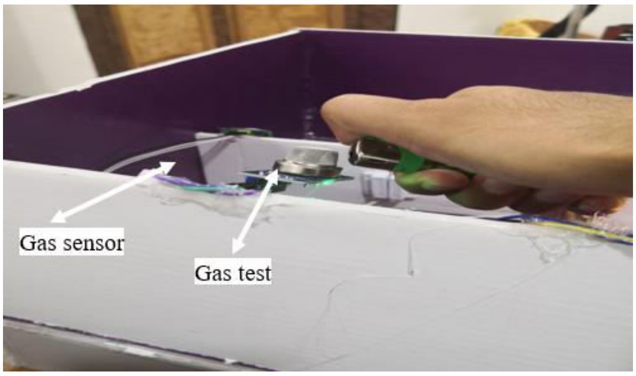


(d)

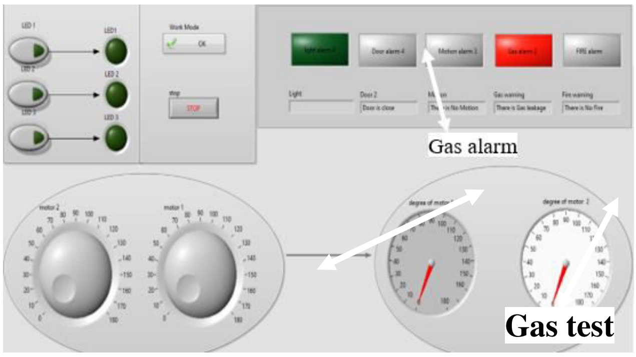
Figure-10. Out-of-work mode test results.

h. All Time Mode Test Results

- When the test gas sensor is under the gas condition as indicated in Figure-11(a), it works well, and the alarm is displayed in the LabVIEW interface as shown in Figure-11(b).
- When the test flame sensor is under fire conditions as presented in Figure-11(c), its response is well and then the alarm is displayed in the LabVIEW interface as revealed in Figure-11(d).



(a)



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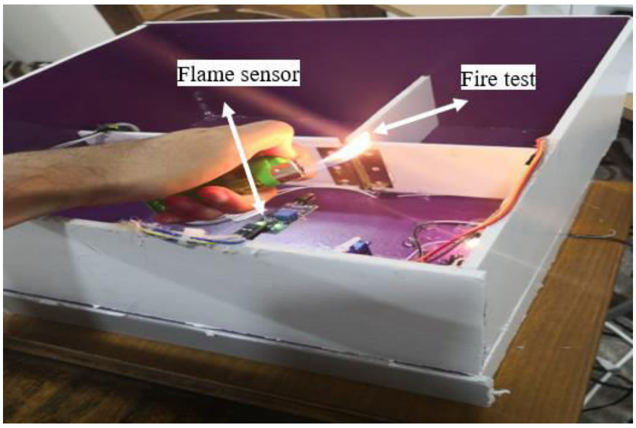

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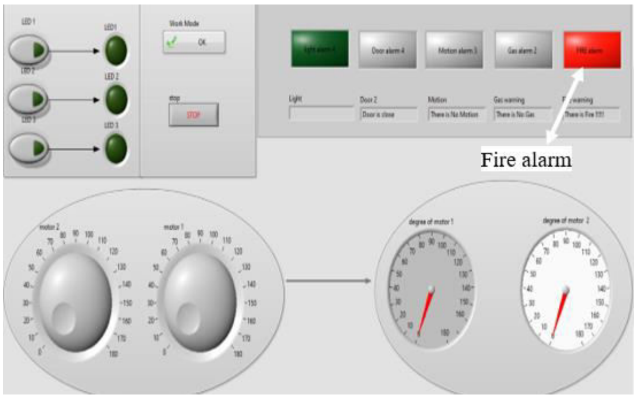
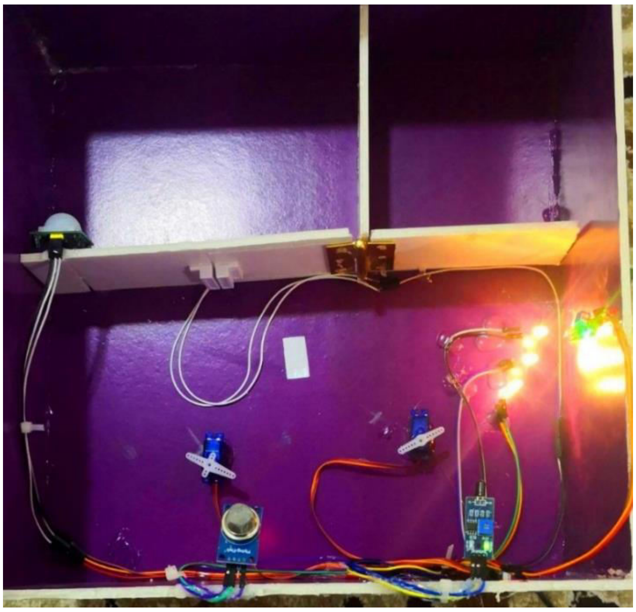


(d)

Figure-11. All time mode test results.

A photograph of the proposed wireless Zigbee-based monitoring system prototype is shown in Figure-12. It is composed of the following components: MQ2, LED, PIR, DHT, Flame sensor, servo motor, magnetic switch door sensor, BH1750 Light Sensor, XBee Module, XBee Adapter, and Arduino. The results show that this proposed wireless system is efficient in controlling and monitoring any industrial automation with high efficiency and low cost. Besides, it is easy to apply in varied areas due to its flexibility and simplicity.

(a)



(b)

Figure-12. Photograph of the proposed system prototype.

4. CONCLUSIONS

This work successfully designed, implemented, tested, and verified a potential wireless controlling and monitoring system using Zigbee technology for industrial automation systems. The proposed system is composed of various components like Arduino, fire sensor, gas sensor, light sensor, motion sensor, door sensor, 3 LED, 2 micro servos, and 2 XBee modules, which operate on ZigBee Technology. The experimental results show that at the working time mode, the system allows the user to turn on the light and indicate its condition through the light sensor. Furthermore, the system offers the ability to switch on or off the engines in the case of out-of-work mode. It is based on detecting movement and door sensors, which function to send alerts when stimulated to protect against theft and intrusion. The fire sensor and natural gas sensor work simultaneously as protection against inflammable resources. This effective wireless monitoring system has economically replaced the problematic wired system. Additionally, the results show that the developed system efficiently controls and monitors the basic parameters for any industrial automation system with improved reliable capability and flexibility at lower power consumption and, thus, cost too.

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