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ORIGINAL CONTRIBUTION

Smart Gas Leak Detection And Emergency Response System Using Iot For Homes

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***Abstract*— As we know, safety is a massive problem in this world today. We can use technology to combat the issue of safety. One of the safety issues is gas leakage, which caused the accident. In this project, we design and develop a system that is based on IoT and detects and monitors gas leakage in real time in homes and small businesses. The project uses NodeMCU as a microcontroller, gas sensors, and other devices like the Wi-Fi module, servo motor, and exhaust fans. This project shows how to integrate different hardware components and hardware with software. The traditional gas detectors found in the market can only alert the user through audio and visual alerts that are only viable if a person is present to combat the issue; what this project does is not only alerts using audio and video, it also alerts the user and the emergency department using a notification sent to an application in the mobile phone. The integration of the app not only increases user interface experience and responsive time but also allows the user to adjust the system's parameters through the app and gives real-time status to prevent accidents; the project also deploys prevention measures such as opening the window, turning on the exhaust, and shutting off the main gas valve to avoid chances of fire and damage.**

Index Terms— **Internet of Things (IoT), Home safety, Mobile interface-based system, Gas leakage, Home automation, Maximum damage control, Continuous gas monitoring**

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I. INTRODUCTION

IoT addresses horizontal markets like industrial automation, healthcare, and environmental monitoring, which have already revolutionized growing benefits. Gas leak detection systems based on IoT are one such application that has added an edge to safety and eliminated probable hazards, and its arena spans domestic and industrial [1]. Gas Leaks Gas leaks, particularly combustible and toxic gases, represent serious risks, i.e., explosions, high fire risk, and poisoning. Traditional approaches for detecting gas leakages involve manual inspections and occasional monitoring that may not occur often enough, leading to late recognition of leaks [2].

LPG and natural gas are widely used energy resources for homes and some industries, and the Green Revolution will increase the consumption of LPG and methane gas. Pakistan is among the developing countries facing multiple challenges in ensuring the safety and security of its citizens and infrastructure [3]. One concern is the threat posed by gas leakages in homes and businesses, which can lead to devastating accidents, causing loss of life and property damage. For instance, in 2020, 1009 incidents happened because of gas leaks, of which 3201 were because of negligence/ smoking, 41 were caused because of the lit candles, and 103 were due to the blast of a gas cylinder, leading to dozens of fatalities and injuries, as well as damage to residential and commercial properties [4]. The proposed project is based on the Internet of Things (IoT), which detects gas leaks in the surroundings, which detect gases in real time [5, 6]. The system also monitors and is designed to take precautionary measures to detect alarming gas leakage. The system uses a NodeMCU board, gas sensor module, servo motors, relay, and a Wi-Fi module. The gas sensor module detects the presence of combustible gases such as Natural gas, CO, or LPG and alerts the NodeMCU [7].

Additionally, NodeMCU sends notifications to an app using the Wi-Fi module and deploys preventative measures [8, 9]. The system is compact, low-cost, and easy to install. This system combats the issue by doing two things: first, after detecting gas leakage, it sends an alert to make the user aware; second, it reduces the amount of gas leaked by pushing it outside using exhaust.

A. RELATED WORK

The authors have reviewed some past documents about gas leakage detection and presentation systems, and then they have come up with the components and methods they may use to make their gas leakage detection of LPG. After reviewing different papers, they have proposed that their project will be IoT-based for the fastest notification; the gas sensors that they would be using are MQ-5 or MQ-6, the microcontroller used will be

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AVR, and to avoid accidents, they will be using a servo motor to shut off the gas valve and use a buzzer and led to alert nearby people for communication they would be using GSM module to send message to alert the user [10].

This paper discusses creating a system designed to detect and monitor gas leaks, specifically for methane and LPG gas in industrial settings. They have used the NodeMCU-1 microcontroller along with an MQ-5 sensor for gas detection. Here's how it works: when the sensor picks up gas, it communicates the concentration levels to the NodeMCU. If those levels exceed a certain threshold, the microcontroller triggers a buzzer to alert workers and others nearby, and it also sends an alert to the company's central monitoring system. In addition, it opens the vents in the section of the facility where the gas is detected to help disperse it [11].

The authors reviewed previous studies on gas leakage detection and presentation systems, which helped them identify the components and methods they could use for their gas leakage detection project focused on LPG. After examining various papers, they decided their approach would use IoT technology for quicker notifications. The gas sensors they plan to use are either MQ-5 or MQ-6, and they'll be employing an AVR microcontroller. To enhance safety, they intend to use a servo motor to close the gas valve and provide alerts through a buzzer and LED. Communication will occur via a GSM module to send messages to alert users [10].

This article outlines a design for an LPG gas leak detector based on a microcontroller that can identify the presence of LPG in the air with an MQ-5 sensor. The device operates by detecting gas via the sensor, which then relays this information to the microcontroller, specifically an ATMega328, a low-power 8-bit microcontroller. When the microcontroller gets data from the sensor, it alerts the user via a message sent through a GSM module called SIMCOM_300 and uses a buzzer and an LED for alerts. To prevent accidents, it also turns on an exhaust fan to help clear gas from the area [12].

In this study, the authors propose an affordable gas detection system equipped with both visual and audio alerts. They are based in Nigeria, and their primary goal is to address the issue of gas leaks in the most budget-friendly manner possible. Essentially, they used an MQ-2 sensor for detection and NodeMCU as the microcontroller to implement their alert system, which includes a buzzer and a small LCD for visual signals. Though the design is quite conventional—focused solely on checking gas concentration and providing alerts—the low cost makes it a great fit for developing countries like Nigeria, where financial constraints are major, and even basic detection can help avert accidents [13].

The authors have introduced a concept for an automatic gas detection robot that is controlled via an Android app. This prototype is meant to routinely scan industrial environments for gas leaks, notifying the user through Bluetooth when a leak is detected. The app not only displays data but also allows users to control the robot's movement using text or voice commands. This robotic solution is ideal for navigating tricky or hazardous areas where human inspectors might face risks. While promising for the industrial sector, it requires additional testing before real-world deployment since it's a relatively new idea in communication. Wi-Fi connectivity might be a better alternative, as it generally offers superior range compared to Bluetooth [14].

This paper proposes a gas monitoring and leak detection design using IoT technology. The system is well-suited for both traditional households and gas filling stations to detect LPG leaks. It features an LCD for information display, a SIM900L for SMS alerts and internet connectivity, an MQ-9 sensor for gas concentration measurement, and a DHT11 sensor for temperature and humidity detection. The microcontroller used is the ATMega328-p. The system alerts users via SMS and stores data on a web server, measuring gas levels, temperature, and humidity for more accurate notifications. They implemented dual alert methods: SMS notifications and data published on a web server [15].

Upon reviewing earlier studies relevant to this project, several gaps were identified, such as the limitation of merely alerting people to gas leaks without taking preventive measures. Rather than relying on simple alarms or lights—prompting individuals to handle the leaks on their own—the proposed system takes proactive steps. It aims to notify relevant authorities (like police, fire brigades, and gas companies) to dispatch professional help and includes automatic preventive measures, like activating exhausts, opening windows, and shutting off gas valves, to minimize the risk of any unfortunate incidents.

II. METHODOLOGY AND SYSTEM DESIGN

The methodology discusses systematic working system architecture, design, and components. The section provides comprehensive details of the critical components used, such as the sensors and microcontroller, and how the overall system interacts with the mobile app wirelessly [16]. The testing and validation process is used to test the system performance under various conditions, including testing the sensitivity and the accuracy of the gas sensors, the reliability of Wi-Fi, the efficiency of the microcontroller, and the rigidness of the preventative measures used [17].

A. System overview

The overview of the system is that we will use MQ-9 gas sensors to measure the concentration level of combustible and harmful gases commonly found in homes, like Methane, Liquid Petroleum Gas (LPG), and Carbon Monoxide (CO). The sensors then send the input data to the microcontroller; the microcontroller used for this project is NodeMCU [18], which is used for its simplicity and ease of integration with various components; the microcontroller then processes the input data from the sensors and checks if the concentration level of gas is above or lower the preprogrammed limit and then perform the predefined task based on this data. These predefined tasks are that if the concentration level is less than the threshold, it will continue to receive data. If the level is above the threshold, it will first generate a notification with the information about the concentration level and then send it to the user through a Wi-Fi module, which will be received by the user on a mobile application simultaneously; it will activate preventative measures to prevent further accident like turning on the exhaust fan and opening windows for ventilation for push out the gas from the area it will also turn off the main gas valve [19].

B. Requirement analysis

This section analyzes the requirements for an IoT-based gas leak detection and home alert system by identifying the functional and non-functional requirements essential for achieving the project's objectives. It outlines the performance criteria for both hardware and software components, including sensor sensitivity, software compatibility, and user interface design, ensuring optimal system functionality. This phase is crucial in guiding the design, integration, and deployment of a system that effectively meets its intended purpose [20, 21].

Circuit design

The circuit diagram represents an IoT-based gas leak detection and alert system designed to monitor gas levels in a home environment and respond proactively to potential hazards. The system is built around a microcontroller (Arduino or ESP8266/ESP32), which serves as the central processing unit, interfacing with various sensors, actuators, and output components to ensure safety, as seen in Figure 1. The gas sensor continuously monitors the environment for gas leaks. If the gas concentration exceeds the safety threshold, the sensor sends a signal to the microcontroller [22]. The microcontroller then activates the buzzer, displays a warning message on the LCD screen, and turns on the exhaust fan to remove the leaked gas. Simultaneously, the servo motor closes the solenoid valve, stopping the gas supply to prevent further leakage. If IoT functionality is enabled, the Wi-Fi module sends an alert notification to the user's mobile device for remote monitoring.

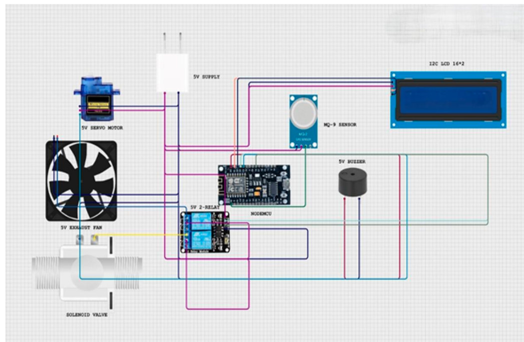

Fig. 1. Circuit diagram

1) Flow chart

The flowchart represents the decision of IoT-based gas leak detection and alert system to manage and make necessary decisions then and there immediately, as in Figure 2. The procedure starts by powering up the system, and the gas sensor allows the environment to be monitored constantly for gas concentration levels. If the gas concentration detected by the system is more than a specified safety threshold, several safety measures are activated by the system; otherwise, it proceeds with regular monitoring.

The system detects the leaks , and the system will take three actions simultaneously: notify the user through notification/alarm; then the servo motor will close the gas valve to stop the supply of the gas, and the exhaust fan will be on to take the gas out of the room. Then, the system checks if the user responds in a timely manner. If a user or admin acknowledges the alert and takes action, the process ends, and the threat has been neutralized. But if the user does not respond, the system generates an alarm (buzzer) to look into.

Next, the system checks if the gas concentration is still increasing. As long as the level of gas is stable, the safety measures will stay lit. However, with a further increase in the concentration of gas, the system escalates the response and alerts the gas company to inspect the area and notify the fire brigade in case of an emergency. It folds to the last step of taking some specific actions if necessary.

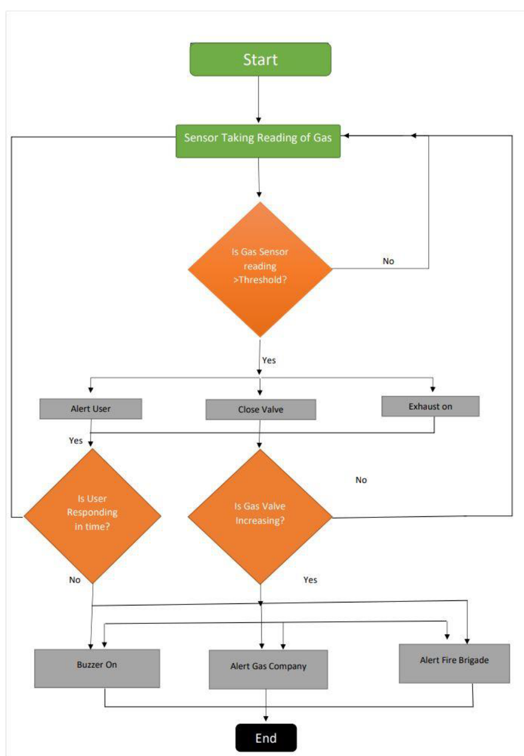

Fig. 2. Flowchart of the operation

2) UML design and ERT diagrams

The UML and ERT Diagrams of the system can be seen in Figures 3 and 4.

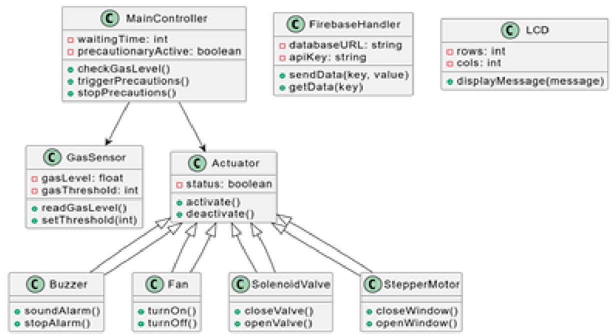

Fig. 3. UML Diagram

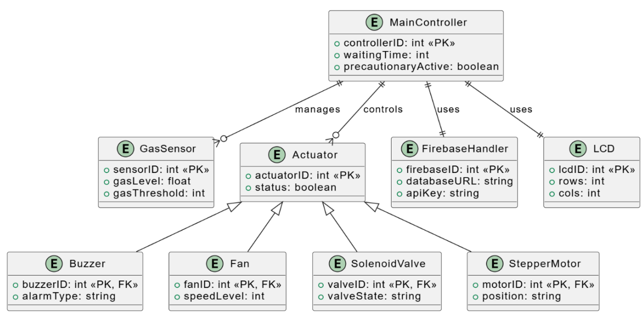

Fig. 4. ERT diagram of the operation

3) Database design

The database has been designed using Firebase Real-time Database because of its real-time data synchronization capabilities, which are very important for IoT-based systems [23]. The hierarchical structure organizes the data into key nodes, enabling efficient data storage and retrieval. The key nodes of the database include nodes such as gas level readings from the MQ-9 sensor, configurable settings for gas threshold and response time, and device statuses for the buzzer, fan, solenoid valve, and stepper motor, tracks the activation of precautionary measures and alert statuses. The design ensures that data is stored and retrieved efficiently, providing rapid updates and robust integration that make it perfect for real-time monitoring and control.

4) Software design

The application has two user ends; one is from where the request (alert is generated along with the message), and the other is receiving (on which the alert is received and the response team is dispatched). The application has been developed using Java programming with the database; the NodeMCU (Microcontroller) has been programmed using its IDE (integrated development Environment), using Python programming, along with the sensor's related modules. Wi-Fi module and relay have been installed to make the equipment compatible with the microcontroller and work. In synchronization, the application can monitor the current gas level in the surroundings; the readings have been transmitted from the system using the Wi-Fi module to the mobile application over the Wi-Fi network [24]. The software enables system users to set the specific parameters and controls to turn off or on the alarm system and activate the ventilation system at its phone controls.

The system relies on communication protocols and libraries like Firebase esp8266 library to connect the microcontroller with the Firebase database; the mobile app communicates with Firebase using SDK to get sensor data, control components, and configure settings. The app's user interface has the option to monitor gas levels and the status of the components, set thresholds, and receive push notifications from Firebase [25, 26]. NodeMcu Ide and Android Studio software are used to program the microcontroller and the Android app. Twilio's API is used to send SMS alerts to emergency services. This software interface makes sure data flows seamlessly, enabling system functionality and user interaction.

The integration of hardware and software is essential for the system's efficient functionality. The NodeMCU microcontroller is used to connect components, i.e., the MQ9 gas sensor, buzzer, servo motor, fan, solenoid valve, and LCD. Firebase's real-time database is used for real-time data exchange between the microcontroller and the mobile app and to manage the device, and Twilio's API is used for sending SMS alerts. The integration ensures real-time response and operation.

III. RESULTS

The results of the developed system are discussed in practical scenarios. Outcomes are compared to predefined objectives of the project, which include near gas detection, activation of precautionary measures, and timely alert. These metrics include the responsiveness of the system, the accuracy of the gas level detection, and the reliability of the Firebase synchronization.

A. Complete hardware

The working prototype of the system can be seen in Figure 5.

Fig. 5. Proposed system working prototype model

The level of the gas in the room environment can be seen in Figure 6.

Fig. 6. LCD shows the gas level

B. B. Mobile application interface

The application interface can be seen in Figure 7.

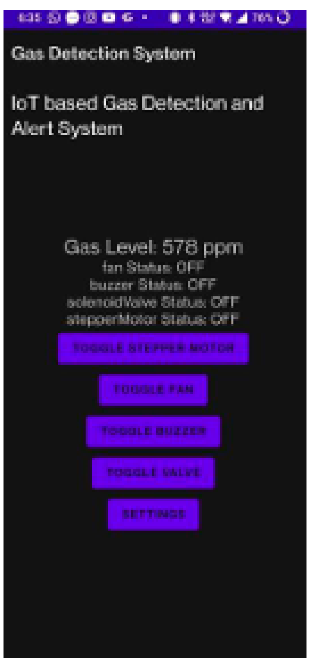

Fig. 7. Mobile application main page

C. Analysis of results

The gas sensor constantly detects and monitors the gas concentration in the app and the LCD, and when the gas threshold (PPM > 900) exceeds the predefined safety limit, the system automatically triggers the safety precautions that are turning on the fan buzzer turning off the gas supply by turning on the solenoid valve. The system was able to not only alert the people in the environment but also reduce the gas concentration in 27 the environment, reducing the chance of an accident. After this, when the gas concentration is below the predefined threshold (PPM < 900), it automatically deactivates the precautionary methods that are turning off the fan buzzer. Secondly, it also updated the gas concentration level and the status of all the components in real-time to the app through the Firebase real-time database. The system also provided real-time push notifications to the app, alerting the user when the gas level exceeds the threshold and when precautionary measures are activated. The user was also able to successfully control the components, like the fan buzzer and valves, from the app and set the gas threshold limit and the waiting time. Secondly, it also updated the gas concentration level and the status of all the components in real-time in the app through the Firebase real-time database. The system also provided real-time push notifications to the app, alerting the user when the gas level exceeds the threshold and when precautionary measures are activated. The user can successfully control the components, such as fan buzzer walls, from the app and is able to set the gas threshold limit and the waiting time from the app. Table 1 below mentions the performance and efficiency of every module of the system as they performed in real-world scenarios.

TABLE I
DETAILS OF PERFORMANCE AND EFFICIENCY OF THE SYSTEM

Scenario	Expected Action	Observed Result
Gas Level > 200 PPM	Activate precautionary measures i.e. buzzer, fan, close window, shut solenoid valve.	The action was executed efficiently, and accurately at the proper time
Gas Level < 200 PPM	Remain idle, Deactivate precautionary measures	The system stayed idle no false activation was observed. and action when required was executed
Loss of Internet Connectivity	Work even offline and sync data when reconnected	The data was successfully to the flirebase upon reconnection
Notification	Notify the user if the gas level exceeds via push notification and emergency services through SMS	The user was successfully alerted through a push notification

D. Discussion of findings

The results obtained from testing the IoT-based gas leak detection and alert system demonstrate that the system is highly effective and reliable in addressing gas leakage issues while ensuring the safety of users. The system consistently detects harmful and flammable gas concentrations with high accuracy, utilizing the MQ-9 gas sensor to monitor environmental gas levels in real-time. Once a gas leak is identified, the system promptly displays the gas concentration on both the LCD screen and mobile application, ensuring that the user is continuously informed of the situation.

One of the key findings is the system's ability to respond accurately when gas levels exceed predefined safety thresholds. In such cases, it immediately activates precautionary measures, including:

- Triggering the buzzer to provide an audible alert.
- Displaying emergency warnings on the LCD screen and mobile app.
- Activating the exhaust fan to remove the leaked gas from the environment.
- Closing the solenoid valve via a servo motor effectively cuts off the gas supply to prevent further leakage.

Additionally, the system's quick alert mechanism ensures that users receive real-time notifications through the IoT-based mobile application. This enables remote monitoring and allows users to take necessary action even when they are not physically present at the location. The findings highlight the system's efficiency in detecting gas leaks, initiating preventive actions in a timely manner, and ensuring a safe living environment.

IV. CONCLUSION

We have completed our IOT-based gas leak and alert system for the home, which detects gas in the surroundings through the sensor(MQ9). Suppose the gas level is higher than the set threshold. In that case, it is going to deploy the prevention measures such as Shutting off the valve, turning the exhaust, sounding the alarm(buzzer), and alerting the user through the app alert. The people in the surroundings may be alerted of potential threats; this can all be controlled by an Android app individually. The app also shows the threshold of the gas currently present in the sensor's surroundings. Through the app, users can set custom thresholds and control valve flow, exhaust, and alarms. The project is more advanced, innovative, and versatile than the previously invented gas detection system. Previous gas detection systems were only detecting gases, and then they sounded their alarms. There were a few that had some prevention measures but were not practical in general. The project detects the gas alarms of the user and takes prevention measures (sounding alarms, generating alerts for users, shutting off the valve, turning on the exhaust to convert the air out from the surroundings to the atmosphere), which reduces the chances of any mishaps to be negligible.

A. Future recommendations

Future recommendations for this project will be to mainly include AI and machine learning algorithms in the system, which can autonomously make more efficient more efficient decisions like setting the guest threshold limit according to the environment and enabling periodic maintenance by checking the functionality of each component in the system furthermore adding advance sensor capable of distinguishing between different types of gases can reduce false error and improve the overall accuracy of the system.

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