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Gas Leak Detection and Monitoring System for Enhanced Safety in Laundry Services

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Abstract

Gas leaks are a significant hazard in the laundry service industry as they can lead to explosions, fires, and toxic gas exposure. This research project aims to develop a gas leak detection and monitoring system that utilizes MQ-2 sensors and an ESP32 controller board. The system includes a database to maintain real-time records of any gas leaks detected by the sensor using the XAMPP server platform. The sensor is placed behind the dryer machine and can detect gas leaks in the 20 cm-1000 cm range. Warning indicators such as LEDs and buzzers alert the user in case of gas leakage. Additionally, a mobile monitoring application named SIN application is developed using Kodular. The system includes a shut-off valve, which allows the user to turn off the gas source valve by switching off the red LED button in the SIN application. When the red LED on the gas leak detector is OFF, this indicates that the connected valve circuit will be closed. Therefore, this project helps laundry service operators improve the level of safety in their facilities by providing a reliable gas leak detection and monitoring system.

Keywords: - Gas leakage detector, gas outflow, Kodular, MQ-2 sensor

1. Introduction

The use of Liquid Petroleum Gas (LPG) is necessary in daily life whether for home use or commercial industry. Liquid petroleum gas, also known simply as propane or butane, is a mixture of flammable hydrocarbon gases used as fuel in heating appliances, cooking appliances and vehicles. LPG is denser than air itself meaning it will flow through the basement. When this situation occurs, the main danger that may be encountered is the possibility of explosion if there is a mixture of LPG and air in the presence of a spark source (Soh et al., 2019). Gas leaks cause impacts that can damage valuable property and human lives.

There have been several cases of explosions due to gas leaks in homes, businesses, and other places. The incident that happened in a residential house in Tasek Gelugor, Penang caused a female victim to burn almost all over her body and damaged the house due to a gas explosion from her kitchen (Berita Harian, December 13, 2022). Another case of an explosion due to a gas leak also occurred in a laundry shop. According to Berita Harian, on April 11, 2018, a gas leak occurred at the premises following the maintenance process on the gas pipeline. The use of non-standard cylinders, old valves, and careless use of gas cylinders are also major causes of such fires and explosions (Dewi & Somantri, 2018). Gas leaks in the premises are often not noticed by the owner until a serious situation such as a fire occurs. Thus, using sensors placed near gas barrels, this development system will help in detecting the presence of gas leaks in laundry shops. Overall, the purpose of this research is to:

i. design a system that can detect gas leakage immediately.
ii. develop a detector that will fabricate sound alarm and send notification alert during gas outflow.
iii. develop mobiles applications for gas leakage monitoring systems using Kodular Apps.

2. Literature Review

In this section, the author summarizes similar studies that have been conducted in the past on LPG gas leak detection systems. Soh et al. (2019) emphasizes the importance of such systems for public safety due to the widespread use of LPG gas in domestic appliances. Paculanan & Carino (2019) and Dwibedi et al. (2020) both proposed LPG gas monitoring systems that use an MQ-2 sensor, an Arduino Uno board controller, and a GSM module for alert notification. Both studies also proposed closing the power supply connected to the gas source when a gas leak is detected. Dwibedi et al. (2020) added a circuit connection to a mini servo motor to open a window as a safety measure to prevent worse effects from occurring due to gas leakage.

Khan (2020) used an Arduino UNO R3, and an MQ-6 gas sensor, which is highly sensitive to propane, butane, and LPG, to detect gas leakage. The MQ-6 sensor updates the gas leakage status within 2 seconds, and an LCD display "Gas detected: Yes" if the sensor output is high and "Gas detected: No" if the sensor output is low.

Bagwe et al. (2018) developed a gas leakage detection system that includes database logging, prediction, and smart alerting features. The system utilizes a NodeMCU board controller, and an MQ-5 gas sensor to detect the concentration of gas in the air. Additionally, the system is integrated with a DHT22 sensor that measures the temperature and humidity of the atmosphere and sends the data to the board controller. The controller then sends the data to a database via XAMPP.

If the gas concentration exceeds a certain level, the system activates a buzzer, GSM module, and LED. The buzzer produces a sound indication, the LED turns on, and the GSM module sends an SMS to the relevant authorities. This project provides a more sophisticated gas detection system that not only alerts users but also logs and predicts gas levels.

3. Methodology

The proposed system architecture is shown in Fig.2 which includes hardware development, database system and mobile apps application.

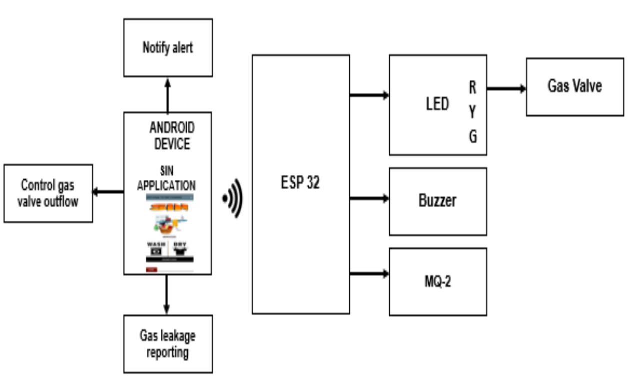


Fig. 1. Project block diagram

3.1 Hardware Development

The main component of the proposed project consists of ESP32 as a main controller, MQ-2 sensor, buzzer module, LED module and jumper wires. The ESP32 has dual-core and ultra-low power co-processor and can control and monitor a device with the help of wi-fi or Bluetooth at a very low price. All input and output components as in Fig.2 will connect to the ESP32 using jumper wire.

Fig. 2. Gas leakage detector component

The MQ-2 sensor has four (4) pins which are VCC, GND, D0 and A0. VCC powers the sensor and needs to be connected to 5V while GND is the ground pin of the sensor. D0 is a digital output pin, which shows the digital representation of the detected gas. While A0 is an analog output pin from which we can detect the type of gas by analyzing the analog value. MQ-2 gas detector is a device that detects the presence of gases in space, typically as part of a safety system. The MQ-2 module can detect H2, LPG, CH4, CO, alcohol, smoke, or propane and the detection range is around 20cm-1000cm (Dwibedi et al., 2020). The sensitivity of the sensor can be adjusted by using the potentiometer (Divyasree, 2019). This sensor was installed behind the dryer machine of laundry prototype.

The traffic light module is a semiconductor light source that emits light when current flows through it. This module has four pins which are pin G (ground), R (red), G (green) and Y (yellow).

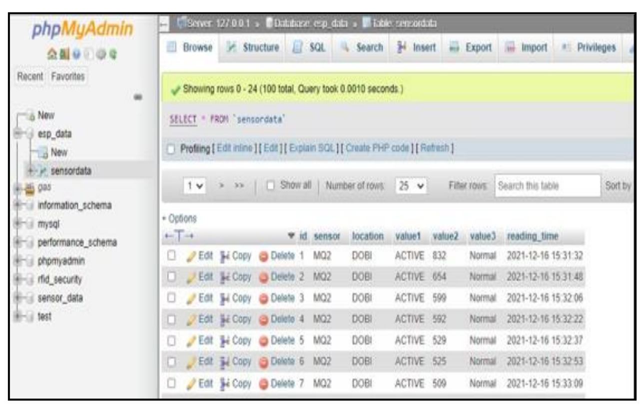


Fig. 3. Validating the data entered into the database

The traffic lights and buzzer modules serve as warning indicators on the proposed project. As specified in the source code written in the Arduino IDE platform, pins 21, 22, and 23 on the ESP32 are connected to the traffic light module. Meanwhile, the buzzer module has three (3) pins: GND, I/O, and VCC. The buzzer I/O pin must be connected to the ESP32's buzzer output pin setting.

3.2 Development of database and mobile monitoring system

This gas leak detector works with the help of the Arduino platform, communicates, and provides continuous feedback with the XAMPP platform to record the gas readings detected by the sensor. Fig 4. shows the platform used for the development of gas leakage detectors.

Fig. 4. The platform used for the development of gas leakage detector

The Arduino platform is a free and open-source platform for creating electronic projects (Divyasree, 2019). In our project, the Arduino platform was used to write source code for giving database responses, working without component errors, and controlling the application as developed. While the XAMPP platform serves as the database system's localhost, it sends each gas leakage data detected by the sensor to the web host. The XAMPP platform allows a local host or server to test a client's website before it is released to the main server. Fig. 6 shows the database records each gas value by displaying gas status, reading time, and location. Each gas detection value takes about 16 seconds to record.

The Kodular platform is an open-source online suite for mobile application development. It has an innovative component and block design that provides free drag-and-drop Android app creators without coding (Syarlisjiswan et al., 2021). This project uses Kodular to develop an application that allows user to monitor the outflow of gas leaks detected with a smartphone. If a gas leak is detected by the sensor, the user is notified via this application.

4. Result and Discussion

Overall, software and hardware parts of the systems have been developed and tested by installing this gas leakage detector to project prototype as shown in Fig. 5.

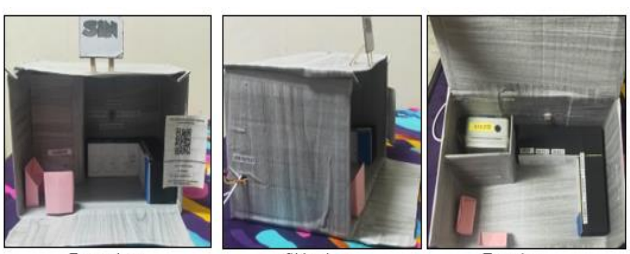
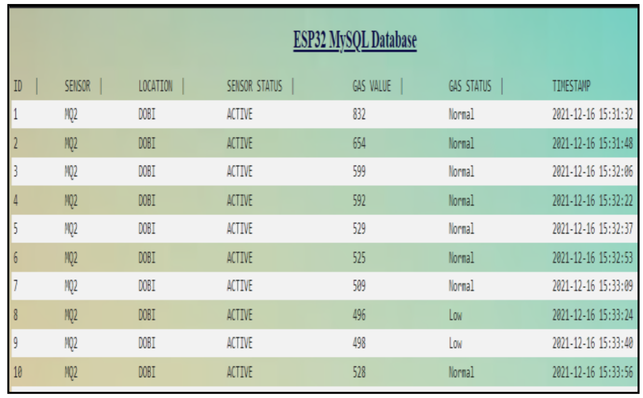


Fig. 5. Different views of the laundry service prototype

The authors created a prototype to demonstrate the project's functionality. This gas leakage detector is placed in the control room. While the gas sensor is placed close to the gas cylinder and dryer. The MQ2 sensor can detect leaking gas within range of 20 cm to 1000 cm. As shown in Fig.6, the database will store each data value detected by the sensor. There are three (3) gas level status values; status value: "Low" if the gas reading value is less than 500. If the gas reading falls between 501 ppm to 999 ppm, the status value will change to Normal. While the High status will record if the gas reading is greater than 1000 ppm. The sensor value will update the reading status every 10 seconds.



ESP32 MySQL Database

ID	SENSOR	LOCATION	SENSOR STATUS	GAS VALUE	GAS STATUS	TIMESTAMP
1	MQ2	DOBI	ACTIVE	832	Normal	2021-12-16 15:31:32
2	MQ2	DOBI	ACTIVE	654	Normal	2021-12-16 15:31:48
3	MQ2	DOBI	ACTIVE	599	Normal	2021-12-16 15:32:06
4	MQ2	DOBI	ACTIVE	592	Normal	2021-12-16 15:32:22
5	MQ2	DOBI	ACTIVE	529	Normal	2021-12-16 15:32:37
6	MQ2	DOBI	ACTIVE	525	Normal	2021-12-16 15:32:53
7	MQ2	DOBI	ACTIVE	509	Normal	2021-12-16 15:33:09
8	MQ2	DOBI	ACTIVE	496	Low	2021-12-16 15:33:24
9	MQ2	DOBI	ACTIVE	498	Low	2021-12-16 15:33:40
10	MQ2	DOBI	ACTIVE	528	Normal	2021-12-16 15:33:56

Fig. 6. Gas Leakage Detector reporting

The gas leak detection and monitoring system also includes a feature that triggers a buzzer sound and LED when the presence of LPG is detected by the sensor. The LED lighting corresponds to the gas reading level. If the reading value is normal (501 ppm – 999 ppm), the green LED lights up. The yellow LED lights up if the reading value is below the set level (< 500 ppm), and the red LED lights up if the gas level status is HIGH (> 1000 ppm). At the same time, the system sends an alert notification to the user. Fig. 7 displays the mobile monitoring application, named SIN application, which was developed using the Kodular platform. To access the SIN application, the user must log in using the correct username and password.

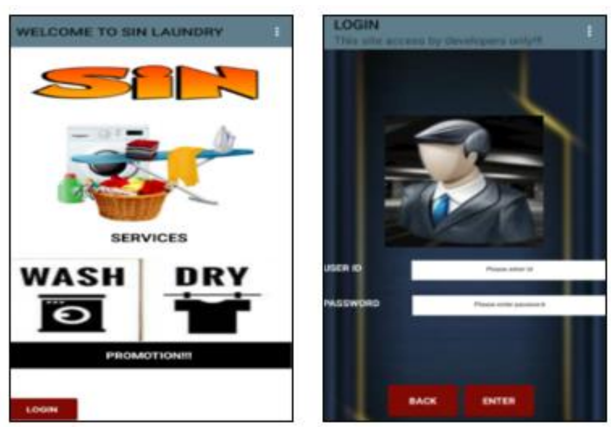


Fig. 7. SIN application security access interface

The gas level status and notifications will appear in a white text box after user slide ON the switch button. If the user does not open the SIN application, the alert message goes into the registered phone notification as shown in Fig. 8.

Fig. 8. Gas level status and alert notification

When the sensor detects a gas leak, it triggers a warning system consisting of a buzzer and LED. This alert signifies a potentially hazardous situation, where the gas can mix with a fuel source and cause an explosion. To address this, the project includes an application that enables the user to close the gas valve source quickly. By pressing the red LED button on the SIN application's display, the gas source valve can be closed, and the red LED on the gas leak detector will turn off. This indicates that the gas leak source has been shut down.

The SIN application allows users to view and download gas reading status reports by clicking the View Report and Download buttons. The gas reading report, as shown in Fig. 9, includes details such as the sensor ID, gas value, gas status, and time stamp. The time stamp corresponds to the sensor's real-time reading. If the user chooses to download the report, it is displayed in pdf format.

Fig. 9. Display of gas reading status

Table 1 indicates that the distance between the MQ-2 sensor and the gas source can affect the sensor's reading. Firstly, as the distance between the sensor and the gas increases, the gas concentration decreases, leading to lower readings from the sensor. Secondly, as the sensor's distance from the gas source increases, its sensitivity may decrease. This is especially true for long-distance readings or sensors that have not been calibrated accurately. Lastly, environmental factors like temperature and humidity can influence the sensor's reading at different distances, as mentioned by Bagwe et al. (2018). Fig. 10 shows the gas reading value and alert notification testing when the gas source is given based on the set distance of 1cm, 5cm, 10cm, 15cm and 20cm. In this study, the author uses a closed box as a laundry shop prototype. While the lighter is used as the source of the gas leak. The test is carried out according to the predetermined distance and time referring Table 1. This MQ-2 sensor is located in the control room and near to the gas piping system of drying machine.

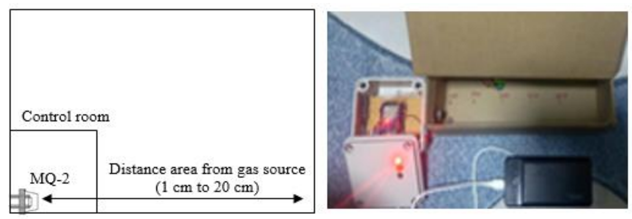


Fig. 10. Gas reading value based on gas leak source distance

The test results depicted in Figure 10 can be cross-referenced in Table 1. This testing specifically evaluates the functionality of the component, considering parameters such as the distance and time of the gas leak test on the sensor. These findings reveal variations in the status of LED lights, buzzer, and notification levels based on the gas leak readings detected by the MQ-2 sensor.

Table 1. Testing component functionality (MQ-2, LED, buzzer) and notification level

Distance (cm)	Preheat Time (minutes)	Status			
		LED	Buzzer	Gas reading value (ppm)	Level
1	1	Red : ON Yellow: OFF Green : OFF	ON	2403	HIGH
5	3	Red : ON Yellow: OFF Green : OFF	ON	1674	HIGH
10	5	Red : ON Yellow: OFF Green : OFF	ON	2003	HIGH
15	7	Red : ON Yellow: OFF Green : OFF	ON	1600	HIGH
20	7	Red : ON Yellow: OFF Green : OFF	ON	1800	HIGH

The gas readings recorded in this study may be less accurate due to the absence of temperature and humidity readings. Temperature changes, the presence of moisture in the air that indicated by the level of humidity can have an impact on gas properties and affect the accuracy of gas leak readings (Bagwe et al., 2018). To ensure the accuracy of gas leak detection, it is important to consider the influence of temperature and humidity on gas properties (Hanwei Electronics, 2006; Bagwe et al., 2018). By measuring these factors along with gas readings, a more comprehensive understanding of gas leaks can be obtained.

Although there are potential limitations in the accuracy of data recorded, this study can serve as a basic guide to understand changes in gas leak readings detected by sensors, as long as the logging data in the developed database is referenced as shown in Fig. 6. The data in Table 1 indicates a high level of sensitivity (High) for the MQ-2 sensor in detecting the presence of LPG gas in the prototype environment. A distance test is conducted, which reveals that the closer the gas source is detected, the higher gas reading is recorded. In summary, by referencing the logged data in the developed database and incorporating time, distance, LED lights, buzzers, and notifications, this study can offer valuable insights into gas detection and its corresponding measurements.

5. Conclusion

The gas leakage detector developed in this study is a useful tool in preventing any potential dangers from gas leaks in self-service laundry centers. It is also part of a system that enhances the safety of the premises. The developed system employs IoT to provide monitoring and control actions, activate alarms, and send warning messages to users in a timely manner. At present, the system enables users to monitor gas status in real-time and generate gas level sensor status reports. Additionally, the system allows users to close the gas valve through a button on the developed application. However, gas valve shut-off controllers connected to gas leak detectors do not yet support this feature. Therefore, the authors suggest that future studies should focus on improving the gas controller shutdown feature, either automatically in the event of a gas leak or through a developed application.

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