Faculty of Electronics and Computer Technology and Engineering

DEVELOPMENT OF IOT BASED GAS LEAKAGE DETECTION AND CONTROL USING MICRONCONTROLLER

SIA WEN HONG

Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours

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A project report submitted
in partial fulfillment of the requirements for the degree of
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DEDICATION

This project report is dedicated to my dear father, SIA TECK KIONG, whose unwavering support has been a constant pillar throughout the entire journey of my research. His encouragement and guidance have been invaluable, and I am grateful for his belief in my abilities.

To my beloved mother, LEE SOK LENG , I extend my deepest appreciation. For months, she has attentively and lovingly encouraged me, providing the truest attention that fueled my work with genuine self-confidence.

I also extend my gratitude to my friends, who have been more than just companions on this academic venture. We've monitored each other's progress, shared insights, and celebrated milestones together. This project is a testament to the collective effort and camaraderie that defined our shared pursuit of academic excellence.

To all those who have worked hard to support and contribute to the completion of this project, I offer my heartfelt thanks. Your efforts have made a significant impact, and I am sincerely grateful for your collaboration.

ABSTRACT

Gas leakage is a serious safety concern in residential, commercial, and industrial settings. Gas leaks can lead to devastating consequences, including fires, explosions, and the potential for loss of life and property damage. Detecting and controlling gas leaks is of paramount importance to prevent such incidents and ensure the safety of individuals and the surrounding environment. Traditional manual inspection methods for gas leak detection are time-consuming and prone to errors. However, with advancements in technology, new and more efficient gas leakage detection and control systems have emerged. This project focuses on the development of an Internet of Things (IoT)-based gas leakage detection system. By utilizing IoT technology, the system aims to provide early warning and response capabilities. The gas sensors able to detect various gases in the air and collected the information as the data. The collected data is transmitted wirelessly to a central control unit for analysis and processing. Advanced data processing algorithms are employed to analyse gas levels and detect anomalies indicative of potential leaks. The system offers real-time monitoring, proactive alert mechanisms, and a user-friendly interface for visualizing gas levels and historical trends. The results demonstrate the effectiveness of the IoT-based gas leakage detection system in accurately detecting gas leaks and facilitating prompt actions. The prototype is cost-effective, as it uses low-cost sensors and microcontrollers. Overall, gas leakage is a critical issue that requires effective detection and control systems. The integration of IoT technology offers significant potential for improving gas leak detection by enabling real-time monitoring, data analysis, and automated responses. These advancements contribute to creating safer environments and reducing the risks associated with gas leaks.

ABSTRAK

Kebocoran gas merupakan isu keselamatan yang serius di perumahan, komersial, dan bidang industri. Kebocoran gas dapat menyebabkan akibat yang menghancurkan, termasuk kebakaran, letupan, dan berpotensi membawa maut serta merosakkan harta. Pengendalian dan pengesanan kebocoran gas adalah sangat penting untuk mencegah kejadian tersebut dan memastikan keselamatan individu dan lingkungan sekitarnya. Cara-cara tradisional untuk mengesan kebocoran gas amat membazirkan masa dan ketidakjituan. Namun, dengan perkembangan kemajuan teknologi, sistem pengesan dan pengendalian kebocoran gas yang lebih efisien telah muncul. Projek ini adalah fokus pada perbangunan sistem mengesan kebocoran gas berasaskan *Internet of Things* (IoT*)*. Dengan memanfaatkan teknologi IoT, sistem ini bertujuan untuk memberikan amaran atau peringatan serta berupaya bertindak balas mengikut keadaan. Penderia gas dapat mengesan pelbagai jenis gas di udara dan mengumpulkanya sebagai data. Data yang terkumpul dikirim secara tanpa wayar ke pusat untuk analisis dan pemrosesan. Algoritma pemprosesan data yang canggih akan digunakan untuk menganalisis aras gas dan mengesan anomali yang mengindikasikan potensi kebocoran. Sistem ini berupaya menjalankan pemantauan dalam masa sebenar, mekanisme peringatan proaktif, dan visual yang mudah difahami digunakan untuk mempamerkan aras gas dan trend sejarahnya. Hasilnya dapat menunjukkan kecekapan sistem mengesan kebocoran gas berasaskan IoT itu adalah dengan tepat dan bertindak dengan segera. Prototaip ini menjimatkan kos, kerana ia menggunakan penderia dan mikropengawal yang kos rendah.Kesimpulannya, kebocoran gas adalah isu kritikal. Dengan integrasi IoT, ia boleh meningkatkan pengesanan gas secara automatik, memastikan persekitaran yang lebih selamat.

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CHAPTER 1

INTRODUCTION

1.1 Background

Gas leakage is a critical issue in various settings, including residential, commercial, and industrial environments. It can result from faulty equipment, aging infrastructure, or human error. Gas leaks, especially those involving highly flammable or toxic gases, can lead to explosions, fires, and adverse health effects. Timely detection and immediate response are crucial to mitigating the risks associated with gas leaks. Traditional gas leakage detection methods often rely on human intervention, periodic manual inspections, or standalone alarm systems. These approaches have limitations in terms of accuracy, efficiency, and real-time monitoring. The emergence of IoT has transformed gas leakage detection by integrating smart technologies and connectivity. IoT refers to a network of interconnected devices embedded with sensors, software, and network connectivity that enables them to collect and exchange data. In the context of gas leakage detection, IoT offers a comprehensive and intelligent solution by leveraging the power of sensors, wireless communication, data analytics, and centralized monitoring.

IoT gas leakage detection systems consist of several interconnected components that work together seamlessly to detect, monitor, and respond to gas leaks. At the heart of these systems are gas sensors. These sensors are designed to detect and measure the concentration of hazardous gases in the surrounding environment. Advanced gas sensors can detect a wide range of gases, such as methane, propane, carbon monoxide, and hydrogen sulfide. These sensors can be deployed at strategic locations, such as near gas pipelines, storage facilities, or areas prone to leaks. Wireless communication is a key enabler of IoT gas leakage detection systems. Gas sensors transmit data wirelessly to a central monitoring system, allowing for real-time monitoring, immediate alerts, and remote access to the system. Wireless communication protocols, such as Wi-Fi, Bluetooth, or cellular networks, ensure seamless and reliable data transmission. This wireless connectivity enables constant monitoring of gas levels and facilitates swift response in the event of a gas leak. Data processing and analysis play a vital role in IoT gas leakage detection. The collected data from gas sensors is processed and analyzed using sophisticated algorithms. This enables the system to differentiate between normal fluctuations in gas levels and actual gas leaks. Machine learning techniques can also be employed to improve the accuracy of gas leak detection by continuously learning from historical data. By analyzing the data in real-time, IoT gas leakage detection systems can promptly identify and alert the relevant authorities about potential leaks, allowing for immediate action. A central monitoring system acts as the command center of the IoT gas leakage detection network. It receives data from multiple sensors, performs real-time analysis, and triggers appropriate responses in case of a gas leak. The central system can be accessed remotely, allowing authorities to monitor and manage gas leakage situations from any location. The monitoring system can generate automated alerts, activate safety measures such as ventilation systems or shut off gas supplies, and dispatch emergency responders if necessary. This centralized approach enhances the efficiency and effectiveness of gas leakage detection and response, minimizing the risks associated with gas leaks. Implementing IoT gas leakage detection systems offer several benefits. Firstly, it significantly improves safety by providing early detection of gas leaks, reducing the potential for explosions, fires, or health hazards. Real-time monitoring ensures that any gas leakage.

Gas leaks are a serious safety concern in various industrial, commercial, and residential environments, which can lead to dangerous situations such as fires and explosions, causing severe damage to properties, injuries, and fatalities. Hence, developing efficient gas leak detection and control systems is crucial in preventing such events. Previously, gas leak detection systems primarily relied on human inspections, which were time-consuming and prone to errors. However, with the advancement of technology, newer and better gas leakage detection and control systems have been introduced, incorporating advanced hardware and software technologies. IoT (Internet of Things) technology has revolutionized gas leakage detection and control systems. IoT-enabled gas sensors can detect the presence of gas in real-time and transmit data to a central control unit. The collected data can be analyzed using machine learning algorithms and other data analytics techniques to identify potential gas leaks or hazards. Besides, IoT-based gas leakage detection and control systems can trigger automated responses such as shutting off gas supplies, activating ventilation systems, or triggering alarms to alert individuals in the area.

As technology continues to evolve, engineers are continually developing innovative solutions to improve the accuracy, efficiency, and effectiveness of gas leakage detection and control systems. As the regulations for gas safety become stricter, the demand for efficient gas leakage detection and control engineering solutions will only continue to grow.

1.2 Addressing Human Safety Through Gas Leakage Detection Project

Ensuring human safety is the top priority when it comes to gas leakage detection projects. Gas leaks pose a significant danger in various settings and can lead to explosions, fires, and other hazardous situations. Traditional methods of visually inspecting gas lines and equipment for leaks are time-consuming and prone to errors. With the advancement of technology, IoT-enabled gas sensors can detect the presence of gas in real-time and transmit data to a central control unit. This data can be analyzed using machine learning algorithms and other data analytics techniques to detect potential gas leaks or hazards. The need for effective gas leakage detection and control engineering solutions will continue to grow with increasingly stringent gas safety regulations.

1.3 Problem Statement

Gas leakage poses a significant risk to human safety in residential, commercial, and industrial settings, potentially leading to explosions, fires, and other hazardous situations. Traditional methods of gas leak detection rely on human intervention, which can be time-consuming and prone to errors. The development of IoT technology has revolutionized gas leak detection and control systems, enabling real-time detection and transmission of data to a central control unit. Microcontroller algorithms and data analytics techniques can analyze the collected data to detect potential gas leaks and hazards. Automated responses triggered by IoT-based gas leakage detection and control systems, such as shutting off gas supplies, activating ventilation systems, and sounding alarms, can help prevent dangerous situations. As gas safety regulations become more stringent, the need for effective gas leakage detection and control engineering solutions will continue to grow.

1.4 Project Objective

The main aim of this project is to propose a systematic and effective methodology to detect the gas leakage system. Specifically, the objectives are as follows:

a) To develop a gas leakage detection system that can detect the presence of gas.

b) To create an IoT-enabled system that can transmit data to a mobile application for analysis.

c) To develop an automated response system worked with Wi-Fi that activate ventilation systems, and trigger alarms to alert individuals in the vicinity.

1.5 Scope of Project

The scope of this project is as follows:

a) Designing and prototyping the gas leakage detector using Esp 32 board and other electronic components.

b) Developing the software code for the ESP-32 board to process the gas sensor module data, detect gas leakage, and trigger the alert system.

c) Integrating the Wi-Fi or Bluetooth module with the gas leakage detector to enable remote monitoring and control.

d) Conducting testing and validation of the gas leakage detector.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Smart City and Smart Home are among the emerging concepts in modern society[1]. The occurrence of gas spills and house fires can lead to significant property damage and losses. For example, leaks of flammable gas, which are highly combustible, can increase the risk of fire and even result in explosions[2]. Therefore, preventing gas leakage events is critical, and the development of effective gas leakage detection and control systems is necessary. The Internet of Things (IoT) has opened up new possibilities for gas leakage detection and control systems[3]. This literature review aims to investigate the latest advancements and challenges in IoT-based gas leakage detection technology.

2.2 Understanding Gas Leakage and Detection with Machine Learning

Gas leakage is a serious problem that can have harmful consequences for human health and safety. Traditional gas detection systems are limited in their ability to detect leaks, as they often rely on binary sensors that only provide a yes/no response. However, recent advancements in machine learning have enabled the development of more accurate and reliable gas leak detection systems[4] shown in Figure 2.1 . Machine learning algorithms can analyze large datasets of gas sensor readings to detect subtle changes in gas concentrations, allowing for early warnings of potential leaks. In one study, a team of researchers developed a gas leak detection system based on machine learning that achieved high accuracy rates for detecting gas leaks in an industrial setting[5]. Other researchers have also demonstrated the effectiveness of machine learning for gas leak detection in various applications, including residential settings[6].

Furthermore, the use of machine learning for gas leak detection is not limited to specific types of gas, as demonstrated in a study where a machine learning algorithm was able to detect leaks of multiple gases, including hydrogen, methane, and carbon monoxide. In addition, the integration of machine learning with Internet of Things (IoT) devices has shown great potential for real-time gas leak detection and monitoring[7]. Overall, machine learning has shown great promise for improving gas leak detection accuracy and reliability, and for preventing accidents and ensuring public safety.

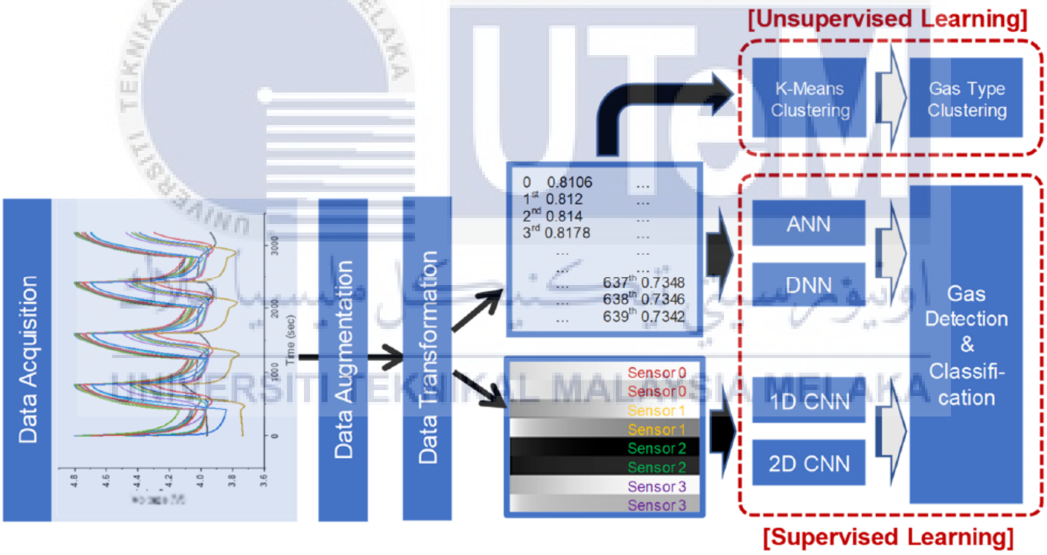

Figure 2.1: Machine learning approaches for gas classification [4]

2.3 Understanding the Limitation of the Gas Leakage Detector with Machine Learning

Although gas leakage detection through machine learning has shown promising outcomes, certain limitations should be considered. One of the primary constraints is the requirement for a large amount of data to train machine learning algorithms effectively. This could pose a significant challenge in environments where data collection is difficult or expensive[8]. Additionally, the potential for false positives or false negatives is another limitation, which may occur if the algorithms are not properly calibrated or if there are environmental factors that affect the sensors[9]. Moreover, the complexity of machine learning models could make them challenging to interpret and comprehend, thus posing a challenge for operators and maintenance personnel[10]. The need for specialized skills and knowledge to develop and maintain these systems is also a barrier to adoption[11].

Despite these challenges, there is still significant interest in using machine learning for gas leakage detection. Researchers are continuously exploring new algorithms and techniques to overcome these limitations and enhance the accuracy and reliability of these systems[12], [13]. Furthermore, the potential benefits of faster and more accurate gas leakage detection make this an area of continued research and development.

2.4 Understanding Gas Leakage and Detection with IoT Microcontroller

Gas leakage and detection have become critical issues in the industrial sector, and the use of IoT in gas detection has provided a significant improvement in gas monitoring systems. IoT-based gas detection systems can remotely monitor the environment, providing real-time data on gas leaks, temperature, and humidity. This enables quick and accurate detection of gas leaks, ensuring the safety of the workers and the surrounding environment. Moreover, IoT-based systems can also automatically trigger alarms and notifications to designated personnel when a gas leak is detected, providing an immediate response to gas leaks[14]. Several studies have been conducted to develop and evaluate IoT-based gas detection systems. In a study by Meshram [15], a wireless sensor network was developed to monitor gas leaks in an underground mine. The system used ZigBee technology to transmit data to a base station, which then sent the data to a cloud server for real-time monitoring. The results showed that the system was effective in detecting gas leaks and could provide timely alarms to prevent accidents.

In another study by Jijusasikumar S [16] an IoT-based gas detection system was developed using a low-cost sensor and a Wi-Fi module as shown in Figure 2.2 . The system was evaluated by measuring the response time of the sensor to different concentrations of gas, and the results showed that the system could accurately detect gas leaks and provide timely alerts.

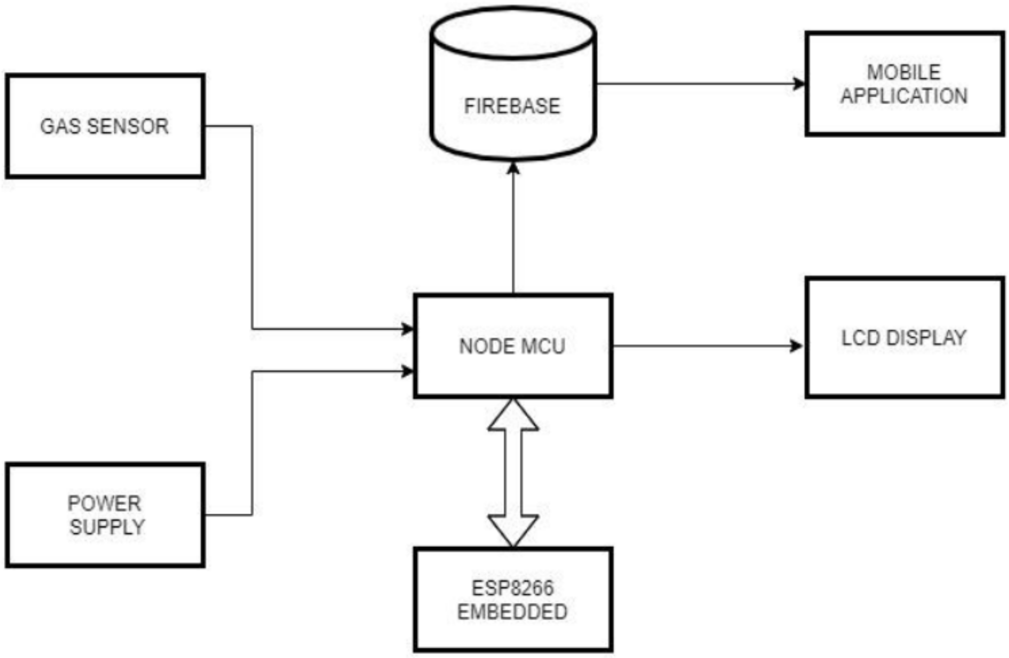

Figure 2.2: Block diagram for the study Jijusasikumar S [16]

Similarly, there is another IoT-based gas detection system developed using a Raspberry Pi and MQ-2 gas sensor. The system was evaluated in a laboratory setting, and the results showed that the system could accurately detect gas leaks and provide real-time monitoring[17]. Overall, the use of IoT in gas detection has shown significant improvements in gas monitoring systems, providing accurate and timely detection of gas leaks. With continuous advancements in IoT technology, it is expected that IoT-based gas detection systems will become more efficient and cost-effective, leading to increased adoption in various industrial sectors.

2.5 Understanding the Limitation of the Gas Leakage Detector with IoT Microcontroller

Gas leakage detectors with IoT technology have emerged as a crucial tool in ensuring safety and preventing accidents. However, these systems have several limitations that need to be understood for their effective use. Firstly, gas leakage detectors with IoT technology have a limited coverage area due to their reliance on sensors. A study conducted by Pandey [18], notes that IoT-based gas detection systems are not suitable for large and complex industrial environments because of their limited sensing range. Secondly, gas leakage detectors with IoT technology are dependent on internet connectivity for transmitting data to a central system for analysis and alerting. Abdul Hannan [19] mentions that this dependence on the internet limits the usability of IoT-based gas detection systems in remote or rural areas where internet connectivity is not readily available. Thirdly, gas leakage detectors with IoT technology are prone to generating false alarms due to sensor malfunction, environmental factors, and interferences[19]. Finally, gas leakage detectors with IoT technology require regular maintenance, including sensor calibration, battery replacement, and software updates, to ensure proper functioning and reliability. The maintenance is a critical aspect of IoT-based gas detection systems[20].

In conclusion, gas leakage detectors with IoT technology have several limitations that need to be addressed to ensure their effective use. These limitations include limited coverage area, dependence on internet connectivity, false alarms, and maintenance requirements. By addressing these limitations, IoT-based gas detection systems can help prevent accidents and ensure safety in various environments[21], [22].

2.6 Summary

In conclusion, the development of IoT-based gas leakage detection systems has shown great potential for enhancing the safety and security of various industries. The integration of various sensors and machine learning algorithms has enabled the creation of more accurate and reliable detection systems. However, there are still some limitations that need to be considered, such as the need for large amounts of data to train machine learning algorithms effectively, the potential for false positives or false negatives, and the complexity of the models. Overcoming these limitations requires further research and development to improve the accuracy, reliability, and interpretability of these systems. Nevertheless, the benefits of faster and more accurate gas leakage detection make this an area of continued interest and investment. All the studies have been thorougly discussed above are summarized in Table 2.1.

Table 2.1: Summary of the previously proposed techniques..

NO	Author	Proposed Method	Advantages	Disadvantages
1.	Oh, JHwang HNam Y et al.[4]	Supervised and unsupervised learning with a 4-SMO gas sensor array	• Integration of supervised and unsupervised learning. • High accuracy and low loss with numerical-based DNNs and image-based CNNs. • Potential for practical sensor networks.	• Limited scalability with sensor array size. • Training data requirements for supervised learning. • Computational complexity of deep learning models.
2.	Zuo et al. 2022[5]	Machine Learning Infrared Focal Plane Detector (Infrared Camera)	• Convenient and non-contact operation. • Improved local contrast for better detection.	• Complex • Limited to indoor conditions. • Lack of direct comparison with other algorithms.
3.	Caldas et al. 2022[6]	Machine Learning Neural Network Model	• Using computational vision.	• Limited to reduced conditions for gas

		Computational Fluid Dynamics (CFD)	• Able to generate realistic leakage.	leakage simulation. • Requires training.
4.	Rashid et al. 2015[7]	Machine Learning smart wireless sensor network (WSN) for leak detection and size estimation in pipelines.	• Enables real-time monitoring of pipeline • Reducing manual response time	• Require significant computational resources. • Noise in data can affect the accuracy of machine learning algorithms.
5.	Hanga K, Kovalchuk Y,2019 [8]	Applying machine learning (ML) and multi-agent systems (MAS)	• Increased effectiveness in production and maintenance tasks. • Potential for better insights and decision-making.	• Limited adoption of ML and MAS in the OGI. • Challenges in integrating different data sources and formats. • Issues with data verification, validation, and security.
6.	Miao et al. 2023[9]	Novel detection (Machine Learning) for determining the	• Reduced reliance on historical failure data for training.	• Reliance on specific signal acquisition methods (residual magnetic effect).

		leakage situation	• Improved detection accuracy • Provides a theoretical basis and new perspective for leakage detection.	• Complexity and needed computational requirements. • Potential limitations in handling real-time detection
7.	Tan et al. 2022[10]	Machine Learning-Combination of Naive Bayes Classifier (NBC) and Probabilistic Neural Network (PNN) for gas leakage monitoring sensor fault diagnosis.	• Enhances the accuracy of sensor. • Feasible and effective for gas leakage monitoring in conditions.	• Dependency on the quality and representativeness of the training data. • Potential limitations in handling complex fault scenarios. • Applicability may vary in different gas monitoring systems. • Need for regular updates and adaptation
8.	Tian et al. 2021[11]	Combines linear fitting and extreme learning machine (ELM) for leak detection	• Improved leak detection • Effective for small gas leakage,	• Dependency on the quality and training data. leakage scenarios. • Maintenance and updates required

			• High detection accuracy	
9.	Sinha et al. 2020[12]	Machine learning architectures such as multi-layer feed forward network, Long Short-Term Memory (LSTM), and convolutional neural network (CNN).	• Automation of leakage detection • efficient and accurate detection. .	• Cost ineffective. • Complexity of machine learning models may require technical expertise for implementation. .
11.	Liu et al. 2023[13]	Machine Learning CNN-TL (Convolutional Neural Network-based Transfer Learning) method for gas leakage detection.	• efficient and accurate leakage detection. • Avoidance of complex signal processing and reliance on expert knowledge. • Reduced computational power requirements.	• Specificity to AE-based leakage detection and convolutional neural networks. • Need for continuous model updates and adaptation to evolving conditions.

12.	Tukkoji Sanjeev Kumar N Assist… 2020[14]	Arduino-based LPG gas detector alarm system.	• Enables timely alerts. • cost-effective solution using Arduino and MQ6 gas sensor.	• Limited to detecting LPG gas leakage only. • No IoT
13.	Meshram et al. 2019[15]	gas leakage system consists of a Wi-Fi module that alerts the user by sending an SMS message	• Early detection of gas leaks, • Automatic control of gas leaks, reducing the risk of fire or explosion.	• Reliance on Wi-Fi connectivity for sending SMS alerts, • High power consumption • Limited range to receive alerts.
14.	Jijusasikumar S et al. 2021[16]	Gas leakage monitoring system using IoT with Node MCU	• Provides real-time alerts and notifications. • Enables remote monitoring.	• Relies on a stable internet connection. • High cost
15.	Sourabh Jamadagni et al. n.d.[17]	Gas Leakage and Fire Detection using Raspberry Pi	• Accurate and cost-effective • Remote monitoring	• Limited to the detection range of the sensors. • Reliance on network

			and control through IoT. • Transparency in monitoring and action-taking.	connectivity for cloud communication. • Limited to detect certain gas only.
16.	Pandey et al. 2018[18]	Microcontroller -based toxic gas detecting and alerting system. Using an ARM Cortex-M4 microcontroller	• Quick response time for detecting gas leaks. • Provides accurate detection.	• Expensive • No exhaust fans. • Large power consumption
17.	Abdul Hannan et al. n.d.[23]	LPG leakage detector system using Arduino with IoT	• Early detection leakage to prevent potential hazards. • Alerts users through email. • Cost-effective solution.	• Limited to detecting specific gases (LPG, propane, butane) • Unfriendly user interface of the IoT
18.	Afifah et al. 2021[19]	liquefied petroleum gas (LPG) leakage detector system using IoT and	• Enables real-time monitoring.	• Limited to detect specific gas only (one sensor only)

		safety alert mechanism.	• Allows remote monitoring and control.	• Limited range of communication for text message and email notifications. • Potential false alarms
20.	Paul et al. 2021[20]	Use a Node MCU ESP8266 microcontroller for system control and data processing.	• Quick Detection . • Enables real-time monitoring	• Installation setup is complex. • Need maintenance regularly.
21.	Imade et al. n.d.[21]	Gas detector sensors, Arduino board, ESP8266, and cloud server are used	• automates gas leakage detection and alerting processes. • Sensor data can be used for further analysis and prediction of hazardous situations.	• Privacy and Security Risks. • Cost ineffective.
22.	Manhas et al. 2021[22]	LPG discharge supported microcontroller -based Node MCU	• Early Warning • Real-time Monitoring	• Limited Gas Detection Type • Reliance on Internet Connectivity .

CHAPTER 3

METHODOLOGY

3.1 Introduction

This section provides an overview of the methods and processes utilized throughout the project. The methodology plays a crucial role in guiding the project's workflow and ensuring its successful completion. It encompasses various sections designed to align the project with its objectives. In addition, flow charts are employed to effectively describe and clarify the workflow, enhancing the project's overall understanding and organization. By following this well-defined methodology, the project can be executed efficiently, fostering the achievement of desired outcomes.

3.2 Overview of the System Block Diagram

The block diagram for the IoT gas leakage detection project which shown in the Figure 3.1 illustrates the main components and their interactions in a concise manner. The system comprises gas sensor modules for detecting gas presence, a microcontroller or IoT device for data processing and communication, a relay module for controlling the exhaust fan, and a central server for data storage and analysis. The gas sensor modules are responsible for detecting gas levels and transmitting the data to the microcontroller. The microcontroller processes the sensor data and activates the relay module when gas leakage is detected. The relay module, in turn, controls the operation of the exhaust fan, which helps to expel the gas and prevent its accumulation. The processed data, including gas levels and fan status, is securely transmitted to the central server through the IoT platform. The server hosts the necessary algorithms for analyzing the data and provides a user-friendly interface for visualizing gas levels, fan status, and historical trends. Additionally, the system incorporates remote notification mechanisms to alert users or relevant personnel about gas leaks and fan operation. By incorporating the relay module, the project enhances the safety measures by automatically controlling the exhaust fan in response to gas leakage. The block diagram demonstrates the integration of hardware components, data processing algorithms, and IoT infrastructure to create an efficient gas leakage detection and control system.

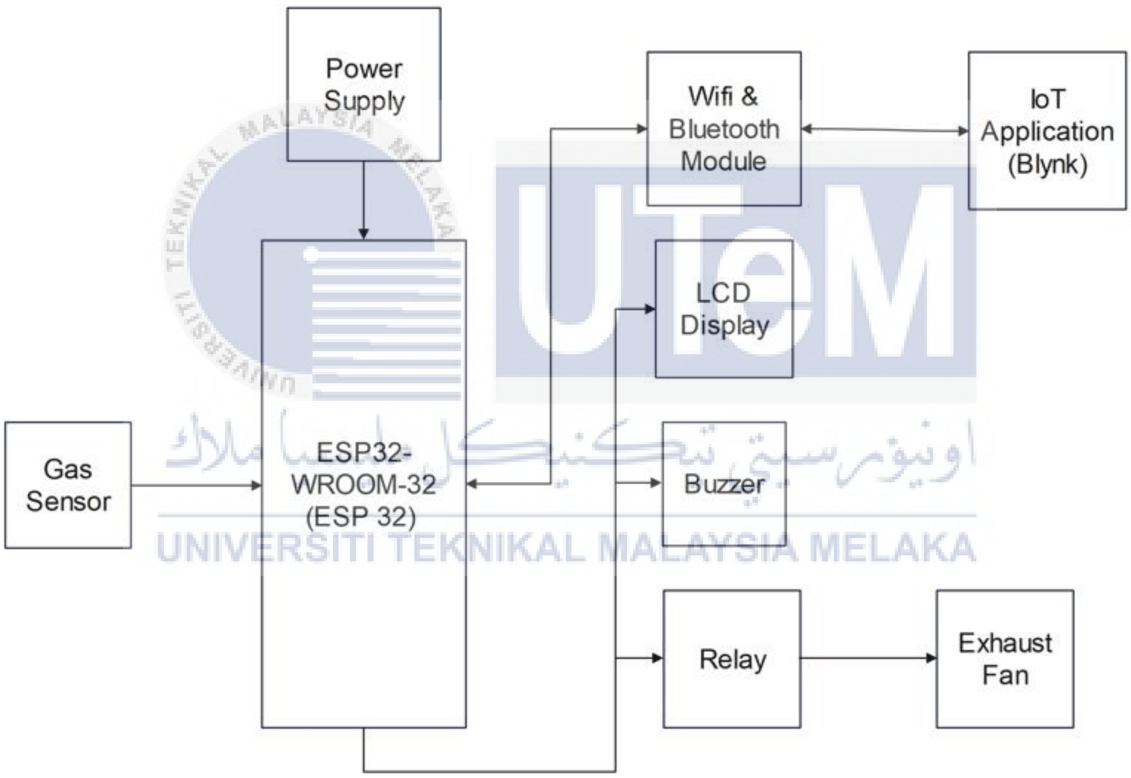

Figure 3.1: Block diagram of the system

3.3 Overview of the System Flowchart

The overview flowchart for the gas detection system as shown in Figure 3.2 follows a specific flow of operations. It starts with powering on the system and acquiring the analog value from the gas sensor. The system then checks if the value obtained is greater than the predefined threshold value. If the value is indeed greater than the threshold, the system proceeds with a series of actions. It displays a warning message on the LCD screen, indicating a dangerous condition. Additionally, it activates a buzzer and LED to provide visual and audible alerts. The system also sends a notification to the user, ensuring they are promptly informed. Furthermore, it turns on the exhaust fan to mitigate the gas concentration. Afterward, it checks if the value has dropped below the threshold. If the value is not above the threshold, indicating a normal condition, the system displays a message on the LCD screen to reflect this. It turns off the buzzer, exhaust fan, and LED, indicating that there is no immediate danger. A notification is sent to the user, updating them about the normal condition. The system then waits for a specified delay before proceeding to obtain the sensor value again.

In the case that the value is below the threshold, signifying a normal condition, the system follows similar steps as mentioned before. It displays a message on the LCD screen, indicating a normal condition. The system turns off the buzzer, exhaust fan, and LED. A notification is sent to the user, informing them about the normal condition. Similar to the previous scenario, the system waits for a specified delay before acquiring the sensor value again. However, if the value is not below the threshold, indicating a dangerous condition, the system takes immediate action. It displays a warning message on the LCD screen, indicating a dangerous condition. The system activates the buzzer and LED to provide alerts. A notification is sent to the user, ensuring they are informed promptly. Additionally, it turns on the exhaust fan to mitigate the gas concentration. This flow of operations allows the gas detection system to continuously monitor the gas sensor values, accurately detect dangerous or normal conditions, and take appropriate actions to ensure user safety.

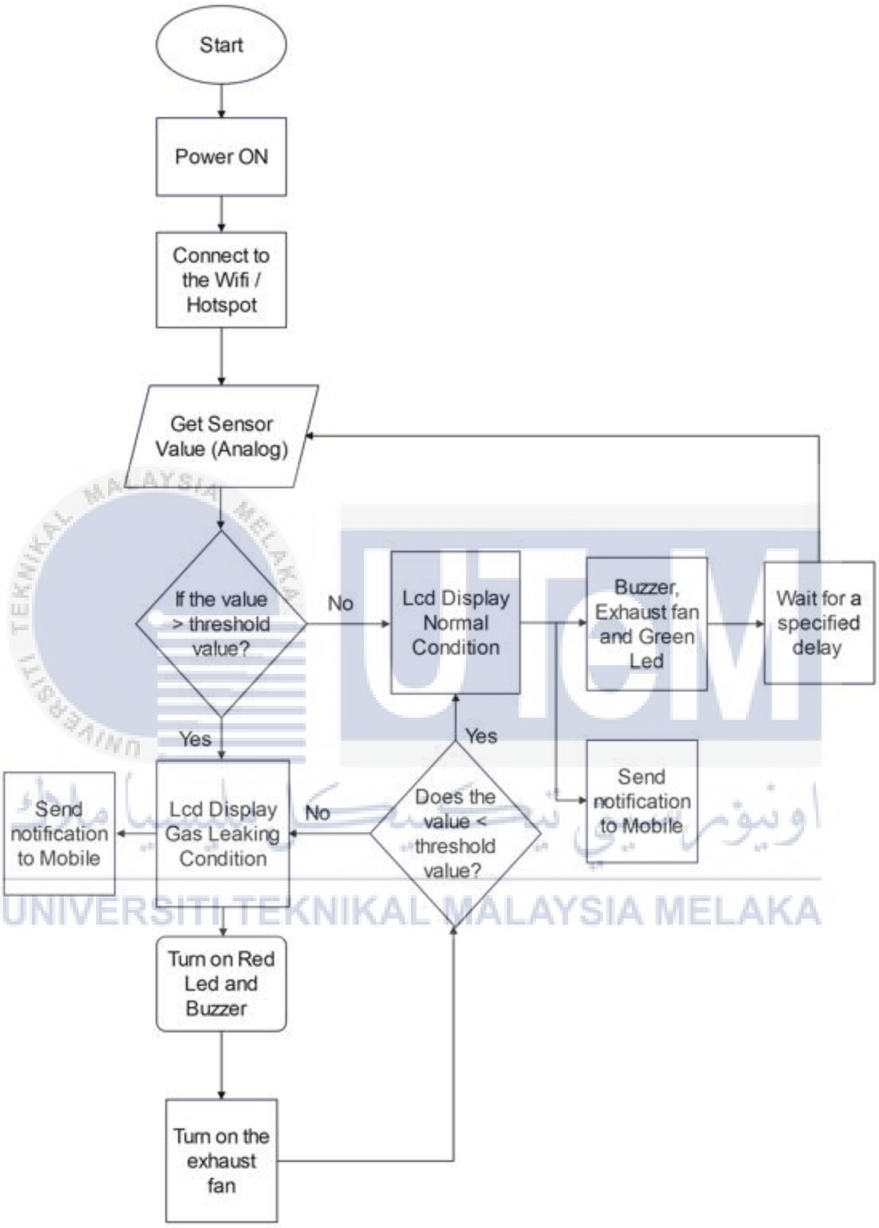

Figure 3.2: Flowchart of the system

3.4 Overview Algorithm Flowchart

The algorithm flow chart shown in the Figure 3.3 initiates by configuring essential components like the ESP32, LCD, LED, Relay, Buzzer, and Gas Sensor. Following this setup, it proceeds to verify the connectivity of the ESP32 to the WiFi network. In cases where the connection fails, it responds by deactivating a yellow LED and reiterates the process of attempting to establish a connection until it succeeds. Once connected, the algorithm signals this success by illuminating the yellow LED. Subsequently, it reads gas sensor values and assesses whether the concentration of detected LPG gas exceeds the predetermined threshold of 30 parts per million (ppm).

In the event of a positive gas detection, the algorithm initiates a series of actions. It displays a gas leakage message on the LCD, activates a red LED for visual indication, sends a notification to a designated mobile device, triggers a relay module, and sets an exhaust fan in motion. Continuing its surveillance, the algorithm monitors gas concentrations, and if the levels fall below the 30 ppm threshold, it shifts its response. At this point, it updates the LCD with a normal message, activates a green LED to signify a safe condition, deactivates the relay module and buzzer, and halts the exhaust fan.

To maintain a continuous operation, the algorithm then loops back to the initial step, checking the ESP32's WiFi connection. This looping structure ensures an ongoing monitoring process for gas levels, intervening promptly to secure the environment against potential gas leaks. This design of algorithm aims to provide a comprehensiveand responsive system for detection and management of hazardous gas situations.

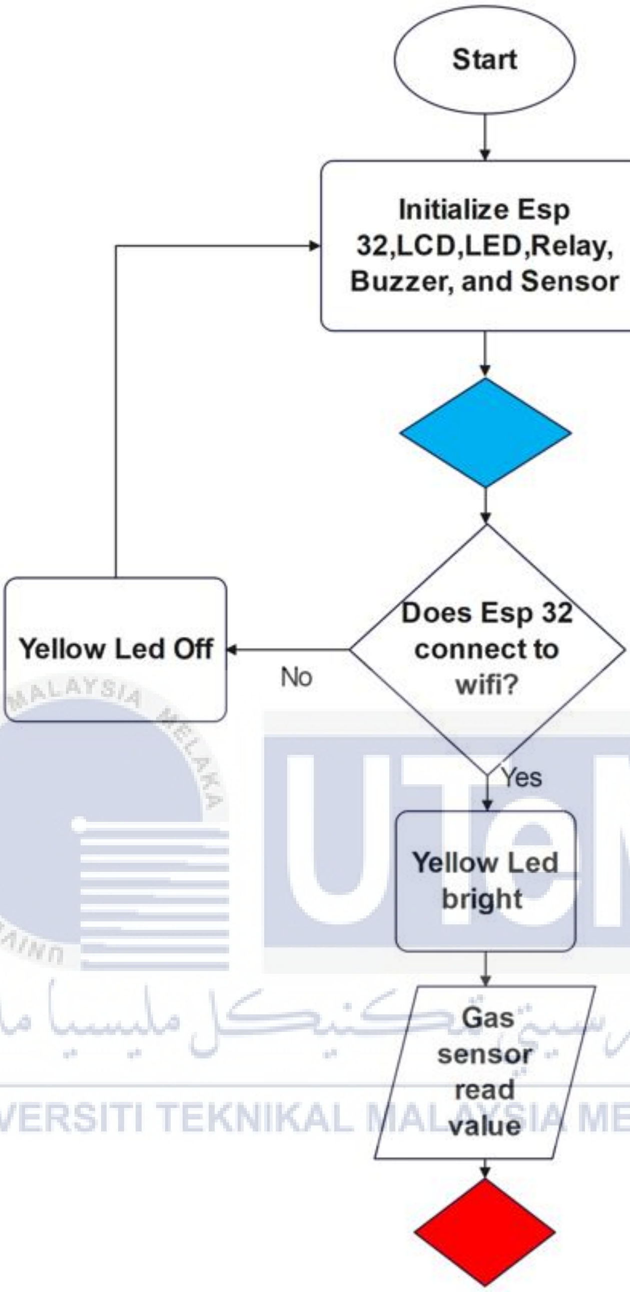

Figure 3.3: Algrorithm flowchart of the system (continue)

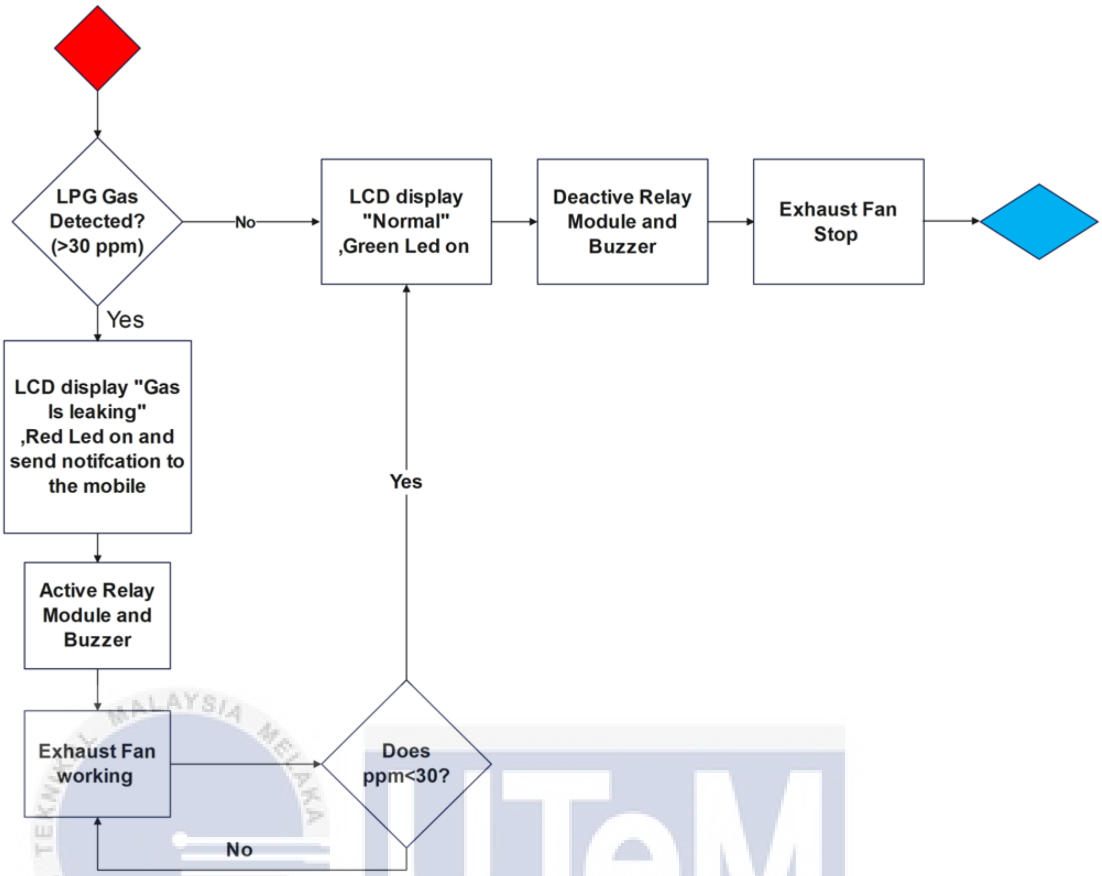

Figure 3.3: Algrorithm flowchart of the system

3.5 Overview of Equipment

3.5.1 ESP-WROOM-32 Module (ESP32 Module)

The ESP32 module which shown in Figure 3.4 is a versatile and feature-rich solution that excels in gas leakage detector projects. It seamlessly integrates with gas sensors, enabling accurate detection of gases such as LPG, methane, or butane. By connecting the gas sensors to the ESP32 module, continuous monitoring of gas concentration levels becomes possible, allowing for timely identification of potential leaks. With its built-in Wi-Fi connectivity, the ESP32 module enables convenient remote monitoring and real-time notifications. It effortlessly connects to local networks or the internet, providing users with the ability to receive alerts and monitor gas levels from any location. Additionally, the module supports data storage, allowing gas concentration(ppm value) data to be logged, analyzed, or transmitted to external storage systems or databases for further evaluation.

Another notable feature of the ESP32 module is its effective control over alarm systems. When gas leakage is detected, it can trigger audible or visual alerts using components such as buzzers or LED indicators. This prompt notification system enhances safety measures by providing immediate awareness of gas leaks. Moreover, the module's compatibility with home automation systems enables seamless integration within smart home setups, facilitating actions such as automated ventilation and integration with other smart devices. To summarize, the ESP32 module's ability to interface with gas sensors, support remote monitoring, control alarm systems, and integrate with home automation systems makes it an exceptional choice for gas leakage detector projects. Its accurate gas detection capabilities, real-time notifications, and flexible integration options contribute to effective gas leak detection and enhanced safety measures.

Figure 3.4: ESP-WROOM-32 module (ESP32 module)

3.5.2 MQ Sensor

MQ sensor ,which shown in Figure 3.5 is a series of gas sensors widely used for detecting and measuring different types of gases. Each MQ sensor is designed to detect a specific gas or group of gases, such as methane, carbon monoxide, alcohol, or various air pollutants. These sensors work based on the principle of chemical reactions between the target gas and the sensing element within the sensor. Inside an MQ sensor, there is a sensitive layer composed of a metal oxide material. When the target gas comes into contact with this layer, it causes a change in the electrical conductivity of the sensor. This change in conductivity is then converted into an electrical signal that can be measured and analyzed.

To use an MQ sensor, it is typically connected to a microcontroller or development board like Arduino or ESP32. The sensor requires a heating element to operate properly, as the metal oxide layer needs to be heated for optimal sensitivity. Once powered on, the sensor starts heating up, and when it reaches the required temperature, it begins detecting the target gas present in the environment. The output of an MQ sensor can be analog or digital, depending on the specific sensor model. Analog output provides a voltage that corresponds to the gas concentration, while digital output may use a threshold value to indicate the presence or absence of the target gas. MQ sensors are popular in gas detection applications due to their low cost, ease of use, and versatility. They find applications in gas leak detection systems, air quality monitoring devices, industrial safety equipment, and more. However, it's important to note that MQ sensors may require calibration and periodic maintenance to ensure accurate and reliable gas detection.

Figure 3.5: MQ sensor (MQ2)

3.5.3 Relay Module

A relay module as shown in Figure 3.6 is an electronic device designed as an electrically operated switch. It consists of a coil, a set of contacts, and a mechanical mechanism for controlling the opening and closing of the contacts. The primary function of a relay module is to provide isolation between the control circuit and the controlled circuit, allowing the control of high-power electrical loads using low-power control signals. When a control signal is applied to the relay module's coil, it generates a magnetic field that activates the mechanical mechanism, resulting in the switching of the contacts. This enables the relay module to serve as a switch that can be controlled by a small electrical signal, while safely handling higher voltages or currents in the controlled circuit.

Relay modules find widespread applications in various domains, including home automation and industrial control systems. They are used to control devices such as lights, motors, solenoids, valves, and other electrical appliances. By utilizing a relay module, the control circuit can efficiently operate high-power devices without directly dealing with the associated high voltages or currents. In summary, a relay module acts as an electrically operated switch, providing isolation between control and controlled circuits. It enables the control of high-power loads through low-power signals and is extensively utilized in diverse applications for safe and effective control of electrical devices.

Figure 3.6: Relay module

3.5.4 LCD Display

An LCD display as shown in Figure 3.7, also known as a Liquid Crystal Display, is a type of flat-panel technology that uses liquid crystals to display visual information. Its primary purpose is to provide a visual interface for users to view and interact with data or information. In project, the LCD display serves as a display medium to present vital information about gas levels and the system's status. It receives data and instructions from the microcontroller or central control unit of the detector and generates text or images based on the received information. The LCD display plays a crucial role in enhancing the user experience by offering real-time feedback and visually representing essential data. It allows users to monitor gas levels, receive alerts or warnings regarding potential gas leaks, and access indicators of the system's operating status. This information empowers users to make informed decisions and take prompt actions, such as evacuating the area or contacting the appropriate authorities.

Overall, the LCD display improves the user interface, making critical information easily accessible and enabling effective monitoring and response in gas leakage detection systems. Its function is to visually communicate important data, thereby enhancing safety and ensuring the efficient operation of the gas detection system.

Figure 3.7: LCD display

3.5.5 Buzzer

A buzzer is an electronic device designed to produce a buzzing or beeping sound upon the application of an electrical current.The design of the buzzer is shown in Figure 3.8 Its primary function is to offer audible alerts or signals in a variety of applications. This includes serving as an integral component in alarm systems for security alerts, acting as indicators to signify task completion or malfunctions, and contributing to communication devices like mobile phones for notification sounds. Buzzers also play a role in gaming, household appliances, medical equipment, and timer/clock devices, serving diverse functions from signaling events to indicating the conclusion of cycles. The choice of buzzer type, whether electromagnetic, piezoelectric, or mechanical, is typically determined by specific application requirements such as sound output and power consumption.

Figure 3.8: Buzzer

3.5.6 Arduino IDE

The Arduino IDE as shown in Figure 3.9 (Integrated Development Environment) is a software application specifically designed for programming Arduino microcontroller boards. It provides a user-friendly interface and a set of tools and libraries that simplify the code development process. The IDE supports a programming language based on C and C++, offering a simplified syntax and a range of built-in functions and libraries for interacting with hardware components. With compatibility across various Arduino board models, the IDE offers consistent programming experience. It includes a text editor for writing code, buttons for compiling and uploading code to the Arduino board, and a serial monitor for debugging and data communication. The Arduino IDE is renowned for its accessibility, making it suitable for beginners and experts alike, and is widely adopted in both hobbyist and professional projects.

Figure 3.9: Arduino IDE

3.6 Limitation of Proposed Methodology

The IoT gas leakage detection system, like any technology, has its limitations that should be taken into consideration. Firstly, the accuracy of the gas sensors used in the system may vary, and they may not always provide precise measurements. There can be slight deviations or errors in the readings, which can affect the overall reliability of the detection system. Another limitation is the detection range of the gas sensors. Each sensor has a specific range within which it can detect gases effectively. If the gas levels exceed this range, the system may not be able to provide accurate readings or detect the gas leakage properly. Regular calibration of the sensors is essential for maintaining their accuracy. Failure to calibrate the sensors periodically can lead to inaccurate readings and reduced effectiveness of the detection system. Proper calibration and maintenance are crucial to ensure reliable operation.

The response time of the gas sensors and the system as a whole is another important factor to consider. There may be a slight delay in detecting and responding to gas leakage events. It's important to account for this response time when designing safety measures and assessing the system's effectiveness in timely detection and alerting. False alarms can also occur with gas sensors, resulting in unnecessary panic or disruptions. Factors such as environmental conditions, sensor malfunction, or interference from other gases or substances can trigger false alarms. Proper calibration and tuning of the system can help minimize false alarms. The system's performance also relies on stable and reliable internet connectivity for real-time monitoring and alerting. Any issues with connectivity or communication between the sensor devices and the central monitoring system can affect the system's performance and timely detection of gas leakage events.

Lastly, the IoT gas leakage detection system requires regular maintenance, including sensor calibration, software updates, and equipment checks. Neglecting proper maintenance can lead to reduced system performance and potential failures. It is important to be aware of these limitations and address them through proper system design, regular maintenance, and ongoing monitoring to ensure the effectiveness and reliability of the IoT gas leakage detection system.

3.7 Summary

The IoT gas leakage detection system is a valuable technology for enhancing safety measures and detecting potential gas leaks. However, it has certain limitations that need to be considered. These limitations include the accuracy of the gas sensors, the detection range of the sensors, the need for regular calibration, the response time of the system, the possibility of false alarms, the reliance on stable internet connectivity, and the requirement for regular maintenance. Despite these limitations, the IoT gas leakage detection system remains an effective tool for monitoring gas levels and alerting users to potential gas leaks, contributing to a safer environment.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the findings and analyses from the development of an IoT-based smart gas leakage detection and control system using Esp 32 module. The case studies are performed to demonstrate the applicability of the system to detect and measure gas ppm. The case study is based on gas samples obtained using an MQ-2 gas sensor. It is important to note that the purpose of these case studies is to demonstrate the proposed methodology regardless of the locations of gas samples obtained. The gas concentration values are obtained by using the proposed approach over a 15-minute timeframe."

4.2 Prototype

The project prototype required several phases to be completed. The prototype is composed of a 7.7V battery for supporting the ESP32, an MQ-2 gas sensor, a relay module, and a separate 9V power source for an external supply to the exhaust fan. The system is powered by direct current (DC) from the 7.7V battery source. Before activating the power supply, it is essential to ensure secure connections between the components. The prototype's casing was designed to conceal wires and other components once accurate and reliable results were achieved. Additionally, a sqaure pp board, represents as the place, was created to showcase how the project prototype would function in real-life scenarios. The top view and the inside view of prototype are shown in the Figure 4.1 and Figure 4.2

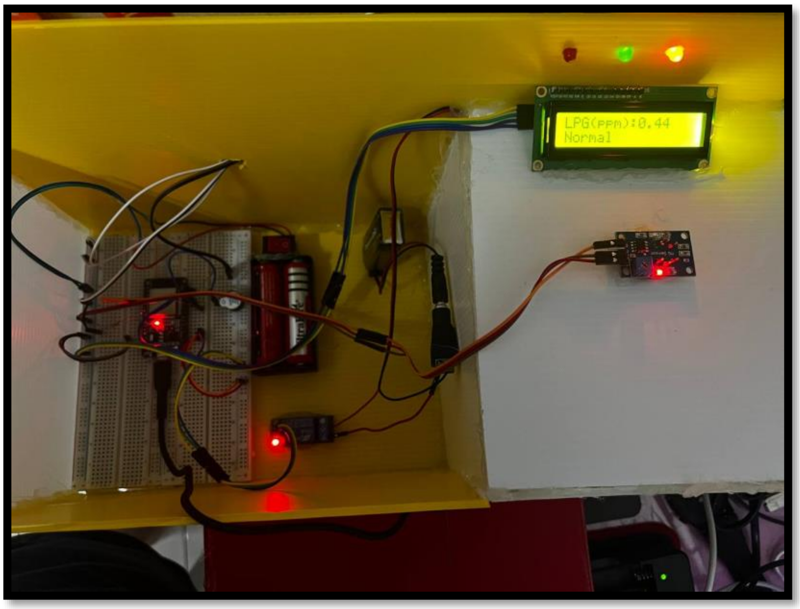

Figure 4.1: Top view of project prototype

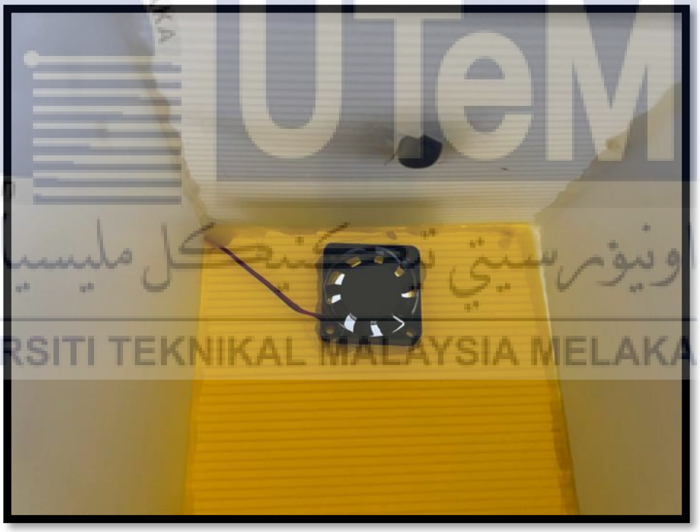

Figure 4.2: Inside view of project prototype

4.3 Results

The results obtained from the gas detection experiment provided valuable insights into the indoor air quality across distinct areas within the living environment. Gas samples were systematically collected from diverse locations, including the living room, balcony, kitchen, and garage. The comprehensive analysis of these samples revealed fluctuations in pollutant concentrations, suggesting spatial variations in the distribution of gases. For instance, the living room exhibited different gas levels compared to the kitchen or garage. These findings underscore the significance of a localized and targeted gas detection system for efficient monitoring and control of pollutants in specific living spaces. Understanding the spatial dynamics of gas concentrations can contribute to the development of tailored strategies to enhance indoor air quality and ensure the well-being of occupants. The collected data not only highlights potential areas of concern but also lays the foundation for further research and refinement of gas detection technologies to address specific environmental challenges in residential settings.

4.3.1 Results of Gas Sample 1 (Living Room)

In the Blynk menu app shown in the Figure 4.3, the gas sensor reports a stable reading of 0.40 ppm, accompanied by the bright illumination of both the yellow and green indicator lights. The yellow light indicates a successful Wi-Fi connection, while the green light assures a standard operational condition. Interestingly, despite the gas reading, the system maintains its equilibrium, with both the buzzer and exhaust fan remaining inactive, as reflected by their lights in the LOW mode within the Blynk menu.

A closer examination of the 15-minute graph that shown in Figure 4.4 reveals a consistent gas level fluctuation between 0.37 and 0.40 ppm, indicative of a steady and typical environment. This analysis suggests that the gas concentration in the monitored space remains within a safe range, as there are no alarming spikes or deviations from the expected baseline.

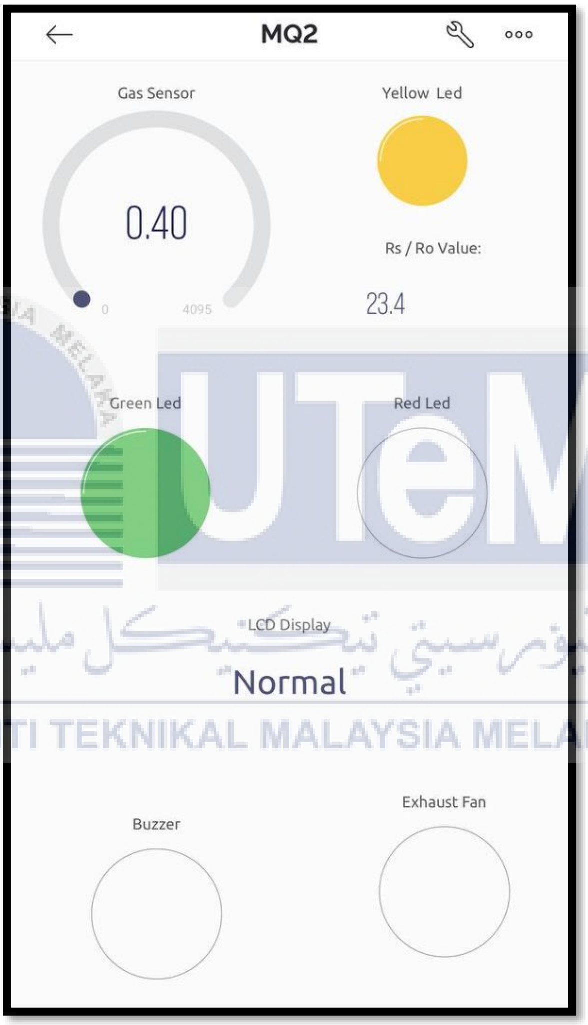

Figure 4.3: Blynk application menu (Living room)

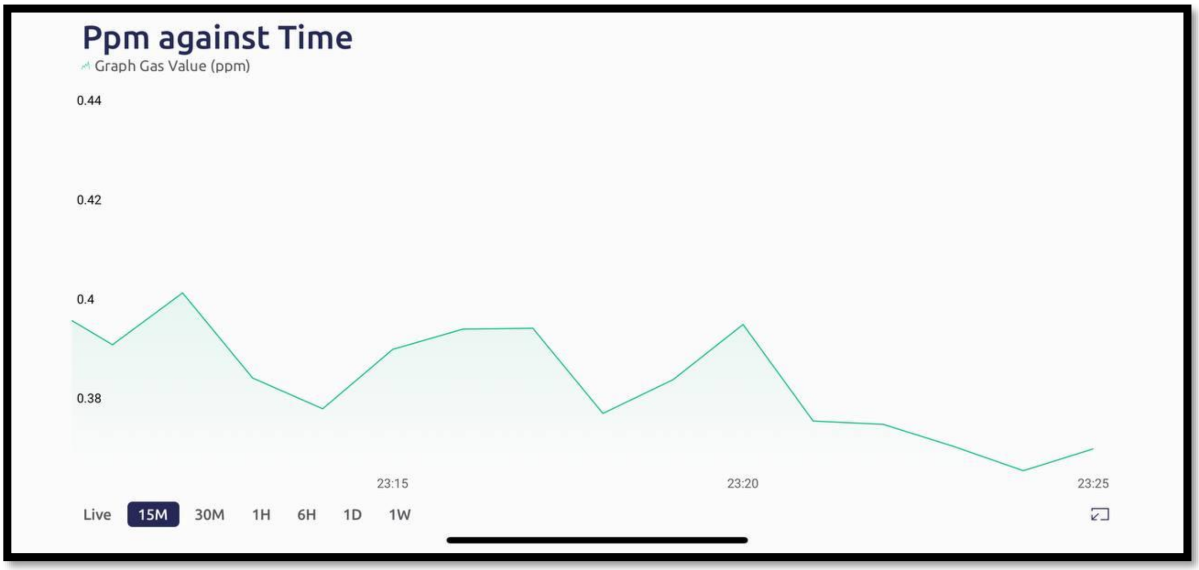

Figure 4.4: Graph obatined from gas sample 1 (Living room)

4.3.2 Results of Gas Sample 2 (Balcony)

In the Blynk app, the gas sensor registers a reassuringly low reading of 0.29 ppm, accompanied by the vibrant illumination of both the yellow and green indicator lights. The yellow light indicates a successful Wi-Fi connection, while the green light assures a standard operating condition. Notably, despite the gas reading, the system maintains a stable state, evident through the inactive status of the buzzer and exhaust fan, as indicated by their lights in LOW mode within the Blynk menu which shown in Figure 4.5.

A closer examination of the 15-minute graph shown in Figure 4.6 provides valuable insights into the system's performance. The consistently low gas levels, hovering below 0.30 ppm throughout the duration, signify a commendable and normal status.

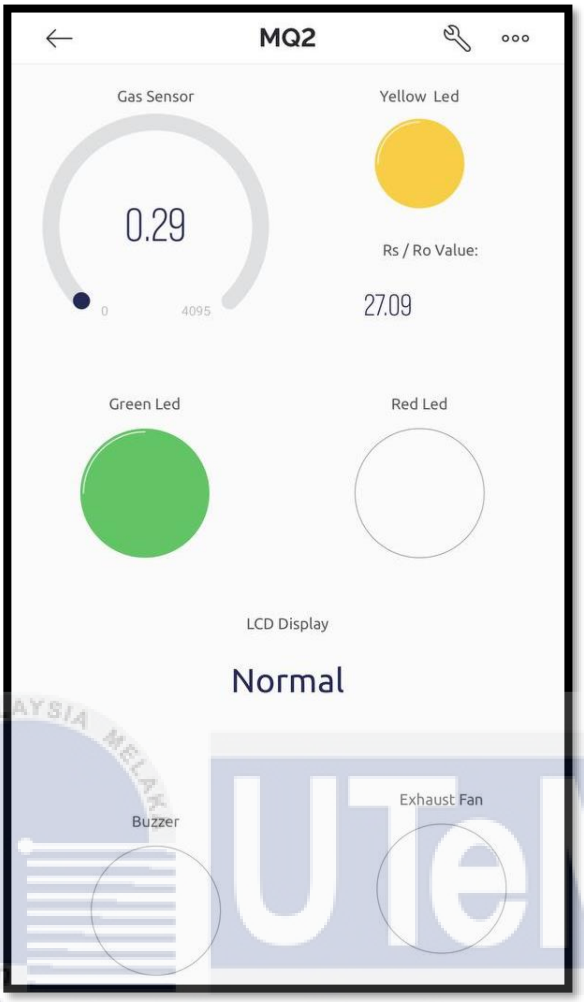

Figure 4.5: Blynk application menu (Balcony)

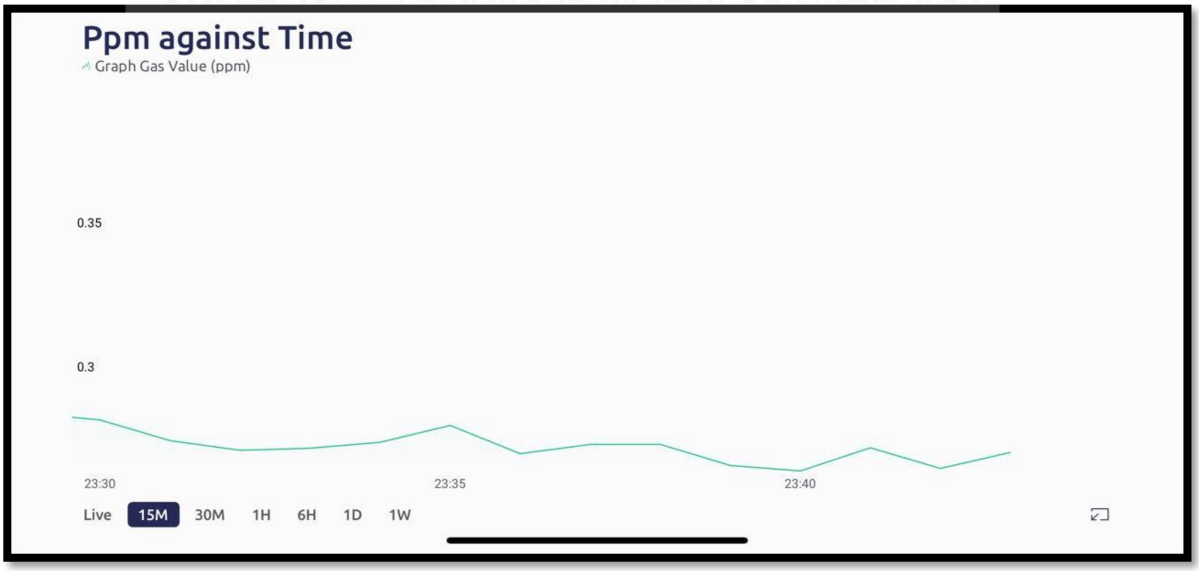

Figure 4.6: Graph obatined from gas sample 2 (Balcony)

4.3.3 Results of Gas Sample 3 (Kitchen)

In the Blynk app as shown in Figure 4.7, the gas sensor is indicating a reading of 11.72 ppm, concurrently illuminating both the yellow and green indicator lights. The yellow light confirms a successful Wi-Fi connection, while the green light assures a standard operational status. Interestingly, despite the elevated gas reading, the system remains in a consistent state, evidenced by the non-activation of the buzzer and exhaust fan, as indicated by their lights in the LOW mode within the Blynk menu.

A more detailed inspection of the 15-minute graph shown in Figure 4.8 exposes a notable spike in the ppm value during the timeframe from 23:45 to 23:50. This sudden increase could be indicative of a transient event or activity impacting air quality in the monitored environment. The system's responsiveness is evident as, after this peak, the ppm value experiences a rapid drop below 5 ppm within a brief period. The subsequent stabilization in the range of 6-7 ppm suggests the system effectively mitigated the impact of the event.

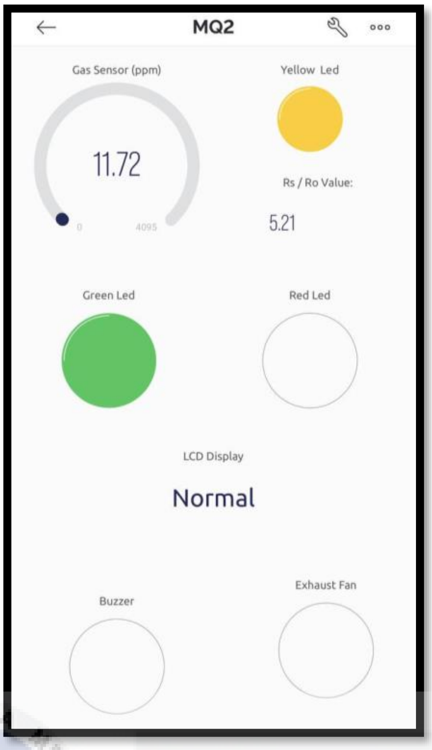

Figure 4.7: Blynk application menu (Kitchen)

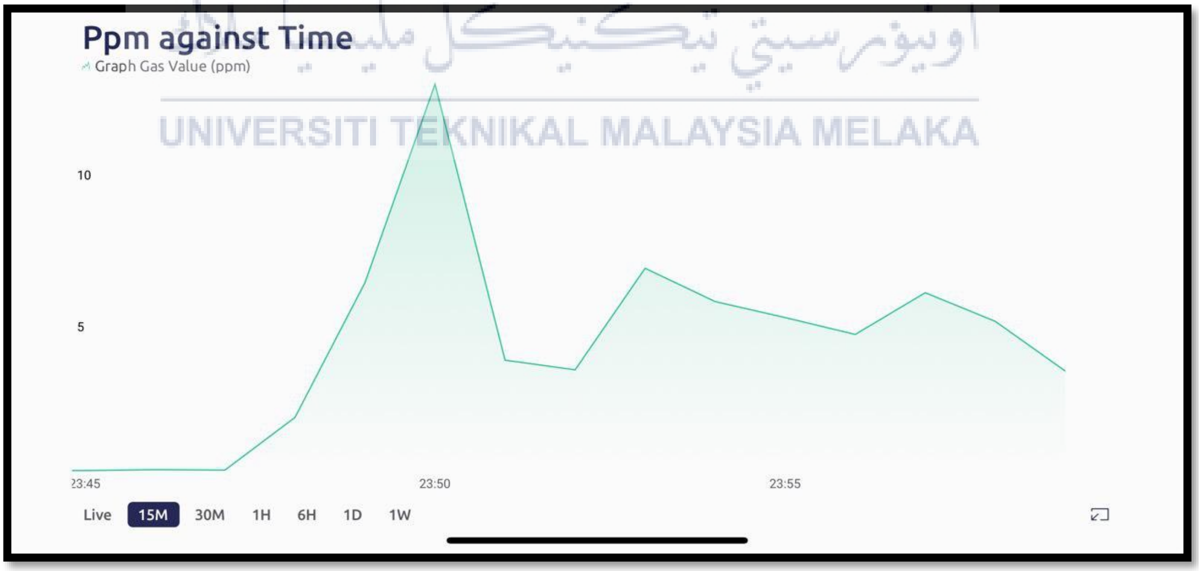

Figure 4.8: Graph obatined from gas sample 3 (Kitchen)

4.3.4 Results of Gas Sample 4 (Garage)

In the Blynk application as shown in Figure 4.9, an alarming gas ppm value of 46.97 is recorded, triggering a series of impactful indicators. The yellow LED brightly shines, affirming a successful Wi-Fi connection, but concurrently, the green LED remains dim, signaling a departure from the standard operational condition. The red LED, now brightly lit, serves as a critical alert, a warning that is reinforced by the LCD display explicitly stating "Gas Leakage Warning!"—an essential notification dispatched to the connected mobile device which shown in the Figure 4.11. Emphasizing the urgency of the situation, the buzzer is activated, adding an audible dimension to the alert. Simultaneously, the exhaust fan is engaged to mitigate the escalating gas concentration. This orchestrated response exemplifies the comprehensive functionality of the monitoring system, effectively communicating and addressing potential hazards in real-time.

As observed from the 15-minute period of the graph in the garage shown in the Figure 4.10, there is a notable and dramatic increase and decrease in the gas ppm values. This trend in the graph, representing the dynamic fluctuations in gas concentration, further underscores the system's adaptability and responsiveness to changing conditions. The graphical representation not only captures the urgency of the gas leak scenario but also illustrates the system's ability to promptly respond to the fluctuating levels, ultimately ensuring the safety of the monitored environment.

Figure 4.9: Blynk application menu (Garage)

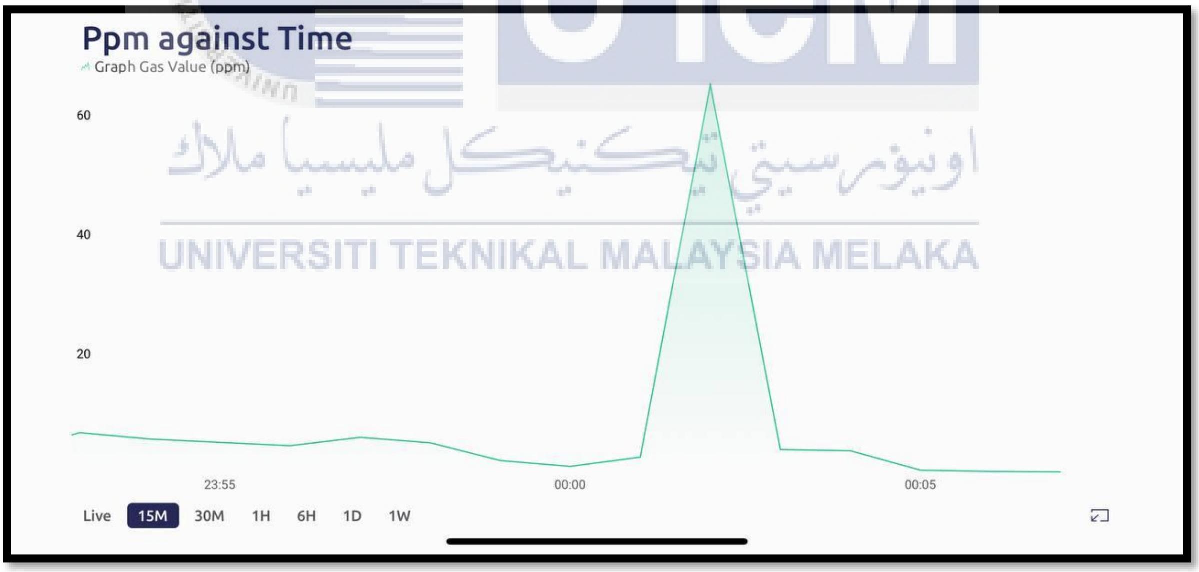

Figure 4.10: Graph obatined from gas sample 4 (Garage)

Figure 4.11: Notification through email when the ppm>30 (Garage)

4.4 Analysis Of All Gas Samples

Bases on the results gas samples above, the slightly higher gas concentration observed in the living room compared to the balcony may be attributed to the inherent nature of indoor environments. Even with sufficient ventilation, indoor spaces tend to retain trace amounts of gases, potentially stemming from household activities, appliances, or building materials. This difference in gas levels between indoor and outdoor areas aligns with expectations, considering that outdoor environments generally benefit from natural airflow and dispersion of gases.

On the balcony, the reassuringly low reading of 0.29 ppm as shown in Figure 4.5 can be attributed to the open-air setting and the presence of good ventilation. Open spaces, free from the confinement of walls, allow gases to disperse more effectively, leading to lower concentrations. The stable gas levels observed on the balcony, as evidenced by the consistently low values in the 15-minute graph which indicate in Figure 4.6, underscore the positive impact of the open environment on maintaining a healthy and safe atmosphere.

In the kitchen, the higher gas reading of 11.72 ppm shown in Figure 4.7 suggests that certain cooking activities, particularly those involving gas stoves, contribute to increased gas concentrations. The notable spike in the 15-minute graph around 23:45 in the Figure 4.8

may be linked to specific cooking events, such as boiling water with a gas kettle. The system's rapid response and effective mitigation, stabilizing the ppm values in the range of 6-7, indicate the successful operation of the ventilation system. This responsiveness is crucial in managing transient increases in gas levels during cooking activities and ensuring a safe kitchen environment.

In the garage, the alarming gas ppm value of 46.97 as shown in Figure 4.9 is likely associated with the presence of a vehicle. The comprehensive response from the monitoring system, including the activation of the red LED, LCD display warning, buzzer, exhaust fan, and also send the alert notification to the user as shown in Figure 4.11 indicates a critical situation, possibly related to a fuel tank leak. The dynamic fluctuations in gas ppm values on the 15-minute graph indicated in Figure 4.10 highlight the adaptability of the system, effectively addressing the issue and ensuring the safety of the monitored environment.

In conclusion, the variations in gas concentrations across different environments are influenced by the specific activities and conditions inherent to each location. The monitoring system's ability to adapt and respond in real-time demonstrates its effectiveness in ensuring the safety and well-being of occupants in diverse scenarios. The detailed analysis of each scenario offers valuable insights into the complex interplay between environmental factors and the system's responsive mechanisms.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In summary, the IoT gas leakage detection system has successfully developed an efficient and affordable system for monitoring gas levels in various environments. By utilizing ESP32 module, relay module, and Blynk platform, this project provides a practical solution to enhance gas safety measures. ESP32 module offer a user-friendly and accessible platform for implementing the gas leakage detection system. With simplified programming and wide community support, the system can be easily set up and configured, even by users with limited technical expertise. The integration of the relay module enables the control of external devices, such as exhaust fans, to mitigate the risk of gas leaks. In case of a gas detection, the system promptly activates the exhaust fan to ensure the safety of the surrounding area. Furthermore, the integration with the Blynk platform allows real-time monitoring, data storage, and visualization. Users can remotely access gas level information and leverage data analytics capabilities to gain valuable insights for proactive maintenance and accident prevention. Overall, the IoT gas leakage detection system presented in this project offers an affordable and efficient solution for gas safety. Its simplicity and integration with cloud platforms make it applicable to various settings, contributing to the overall well-being and security of individuals and communities. Future enhancements can further expand its capabilities and adapt it to specific needs.

5.2 Potential for Commercialization

Based on the development and features of my IoT gas leakage detection system, it possesses significant potential for commercialization. The market demand for reliable and efficient gas detection systems is on the rise, driven by safety regulations and the increasing emphasis on proactive gas safety measures. My project's utilization of affordable components, such as , ESP32 module, relay module, and the Blynk platform, enhances its commercial appeal. The cost-effectiveness of own solution makes it accessible to a broad range of customers, including individuals, small businesses, and larger enterprises. Moreover, the modular design of my system allows for scalability and customization to suit various environments, from homes and offices to factories and laboratories. The integration of multiple sensors, real-time monitoring, and control capabilities gives your system a competitive advantage by offering a comprehensive solution for gas safety. Customers can have peace of mind knowing that potential gas leaks can be promptly detected and addressed.

The user-friendly nature of ESP32, coupled with simplified programming and extensive community support, ensures that users can easily set up and operate the gas leakage detection system without requiring extensive technical knowledge. Additionally, potential partnerships with gas safety equipment manufacturers, distributors, and service providers can further enhance the commercialization prospects of this system. Collaborations can streamline production, distribution, and customer support, enabling a wider market reach. To fully capitalize on the commercial potential of this IoT gas leakage detection system, it is essential to conduct thorough market research, assess competition, and validate its commercial viability through pilot testing and customer feedback. With effective marketing strategies, strategic partnerships, and continuous product improvement, this system can successfully penetrate the market and meet the gas safety needs of diverse industries and consumers.

5.3 Future Works

In the future, there are several suggestions for further development and enhancement of my IoT gas leakage detector:

i. Advanced Sensor Integration: Explore the integration of cutting-edge gas sensors with improved sensitivity and precision. By incorporating state-of-the-art sensor technologies, we can expand the detection capabilities of our system to encompass a wider range of gases and achieve more accurate measurements. Additionally, consider integrating additional environmental sensors to monitor parameters such as temperature, humidity, and air quality, providing a comprehensive safety assessment.

ii. Wireless Connectivity Expansion: Investigate the utilization of alternative wireless communication protocols, such as Lora WAN or NB-IoT, to extend the range and coverage of our system. This would enable us to deploy the gas leakage detector in remote or large-scale environments where Wi-Fi connectivity may be limited. The implementation of these protocols can enhance the flexibility and scalability of our system.

iii. Mobile Application Development: Develop a dedicated mobile application that enables users to remotely monitor gas levels, receive real-time alerts, and control the system. The application should provide an intuitive user interface, granting convenient access to historical data, system settings, and notifications. This mobile integration enhances user convenience and facilitates seamless interaction with our gas leakage detector.

iv. Data Analytics and Machine Learning: Implement advanced data analytics techniques and machine learning algorithms to analyze the collected gas data. This can enable our system to identify patterns, correlations, and anomalies, improving its ability to detect potential gas leaks accurately. By leveraging machine learning models, our system can learn from historical data and enhance its predictive capabilities, distinguishing between normal variations and actual gas leakage events more effectively.

v. Integration with Smart Home Systems: Seamlessly integrate our gas leakage detector with existing smart home automation systems, such as Google Home or Amazon Alexa. This integration would allow users to control and monitor the gas detection system using voice commands, as well as automate actions based on detected gas levels. By aligning with the broader smart home ecosystem, our gas leakage detector can provide a more cohesive and interconnected user experience.

vi. Energy Efficiency Optimization: Optimize the power consumption of our system through the implementation of power-saving techniques and exploration of alternative energy sources. This could involve incorporating energy-efficient components, optimizing data transmission intervals, and considering renewable energy options like solar power or rechargeable batteries. Enhancing energy efficiency would improve the longevity and reliability of our system.

vii. Regulatory Compliance and Certifications: Ensure that our gas leakage detector meets relevant safety standards and certifications, enhancing its credibility and market acceptance. Complying with industry regulations and obtaining certifications demonstrates our commitment to quality and safety, instilling trust in potential customers and facilitating the commercialization of our product.

viii. User Interface and Design Refinement: Continuously improve the user interface and overall design of our system to enhance usability and aesthetics. Incorporate user feedback and conduct usability tests to identify areas for improvement. Strive for an intuitive user interface, clear visual displays, and user-friendly controls to ensure a seamless and engaging user experience.

By pursuing these future works, we can further advance the functionality, performance, and market potential of our IoT gas leakage detector. These enhancements will contribute to a more robust, user-friendly, and innovative solution, catering to the evolving needs of our customers and ensuring the commercial viability of our product.

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APPENDICES

Appendix A   Project Coding

```
#define BLYNK_TEMPLATE_ID "TMPL6v4I7TYKU"
#define BLYNK_TEMPLATE_NAME "MQ2 GAS DETECTOR"
#define BLYNK_AUTH_TOKEN "7QauDFY1H4TF7dGAfqXvwyCu0i2RX3Of"
#define BLYNK_PRINT Serial

#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>  // Include the LCD library

BlynkTimer timer;

// You should get Auth Token in the Blynk App.
// Go to the Project Settings (nut icon).
char auth[] = BLYNK_AUTH_TOKEN;

// Your WiFi credentials.
// Set password to "" for open networks.
char ssid[] = "DuperNene";
char pass[] = "neneisgood";

#define MQ2 34
#define GREEN 19
#define YELLOW 26
#define RED 23
#define RelayPin 15
#define BUZZER_PIN 18  // Update this line to set the buzzer pin as OUTPUT

```

```
// LCD Configuration
LiquidCrystal_I2C lcd(0x27, 16, 2);  // Address 0x27, 16 columns, 2 rows

#define ResistanceValue  10
#define m  -0.4437
#define b  1.1915
#define Ro  2.76

float VRL;
float RsValue;  // Renamed from Rs to avoid macro conflict
float ratio;
float ppm;

// Blynk App control functions for other devices
BLYNK_WRITE(V1) {
    int pinValue = param.asInt();
  if (param.asInt() == 1) {
    // execute this code if the switch widget for FAN is ON
    digitalWrite(RelayPin, HIGH);
  } else {
    // execute this code if the switch widget for FAN is OFF
    digitalWrite(RelayPin, LOW);
  }
}

```

```
BLYNK_WRITE(V3) {
  if (param.asInt() == 1) {
    // execute this code if the switch widget for GREEN LED is ON
    digitalWrite(GREEN, HIGH);
  } else {
    // execute this code if the switch widget for GREEN LED is OFF
    digitalWrite(GREEN, LOW);
  }
}

BLYNK_WRITE(V4) {
  if (param.asInt() == 1) {
    // execute this code if the switch widget for YELLOW LED is ON
    digitalWrite(YELLOW, HIGH);
  } else {
    // execute this code if the switch widget for YELLOW LED is OFF
    digitalWrite(YELLOW, LOW);
  }
}

BLYNK_WRITE(V5) {
  if (param.asInt() == 1) {
    // execute this code if the switch widget for BUZZER is ON
    digitalWrite(BUZZER_PIN, HIGH);
  } else {
    // execute this code if the switch widget for BUZZER is OFF
    digitalWrite(BUZZER_PIN, LOW);
  }
}

```

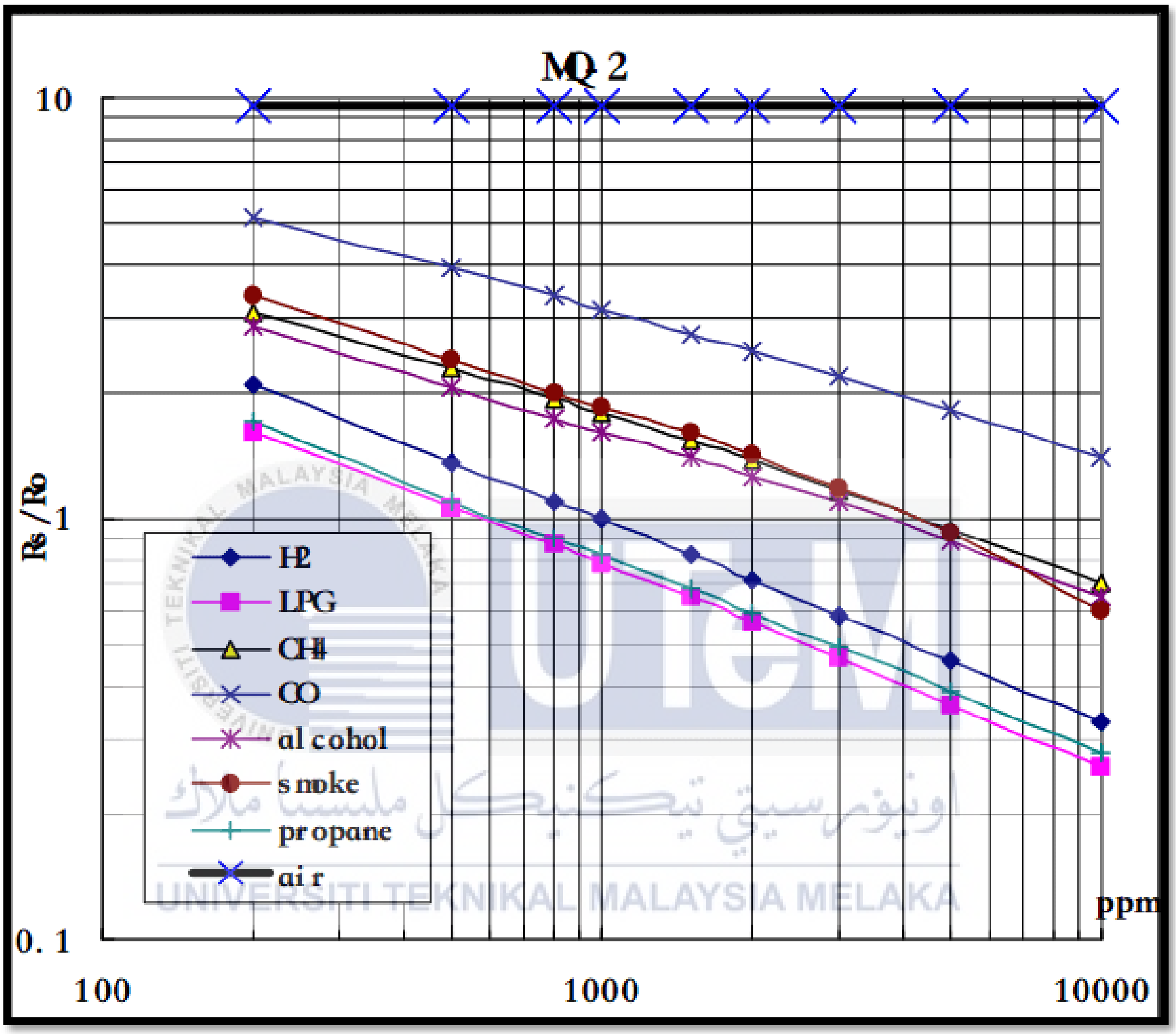
```
BLYNK_WRITE(V6) {
  if (param.asInt() == 1) {
    // execute this code if the switch widget for RED LED is ON
    digitalWrite(RED, HIGH);
  } else {
    // execute this code if the switch widget for RED LED is OFF
    digitalWrite(RED, LOW);
  }
}

void setup() {
  Serial.begin(115200);
  Blynk.begin(auth, ssid, pass, "blynk.cloud", 8080);
  pinMode(MQ2, INPUT);
  pinMode(GREEN, OUTPUT);
  pinMode(RED, OUTPUT);
  pinMode(YELLOW, OUTPUT);
  pinMode(RelayPin, OUTPUT);
  digitalWrite(RelayPin, HIGH); // Relay is off at startup
  pinMode(BUZZER_PIN, OUTPUT);  // Set the buzzer pin as OUTPUT

  // Initialize LCD
  lcd.init();
  lcd.clear();
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("LPG(ppm):");
  lcd.print(ppm, 2);

```

```
  lcd.setCursor(0, 1);
  lcd.print("Initialising~");

  // Allow time for LCD initialization
  delay(2000);
}

void loop() {
  Blynk.run();
  if (Blynk.connected()) {
    digitalWrite(YELLOW, HIGH);
  } else {
    digitalWrite(YELLOW, LOW);
  }

  VRL = analogRead(MQ2) * (5 / 4095.0);
  RsValue = ((5 * ResistanceValue) / VRL) - ResistanceValue;
  ratio = RsValue / Ro;
  ppm = pow(10.0, ((log10(ratio) - b) / m));

  lcd.setCursor(0, 0);
  lcd.print("LPG(ppm):");
  lcd.print(ppm, 2);

  Serial.print(" Rs/Ro = ");
  Serial.print(ratio);
  Serial.print(" LPG(ppm) = ");
  Serial.println(ppm);

  Blynk.virtualWrite(V0, ppm);

```

```
lcd.setCursor(0, 1);

if (ppm > 30) {
  Blynk.virtualWrite(V2, "Gas Leakage Warning!");
  Blynk.virtualWrite(V7, ratio);
  Blynk.virtualWrite(V1, 1);
  Blynk.virtualWrite(V3, 0);
  Blynk.virtualWrite(V4, 1);
  Blynk.virtualWrite(V5, 1);
  Blynk.virtualWrite(V6, 1);

  Blynk.logEvent("gas_leakage");

  lcd.print("Gas Leakage ");
Serial.print("Condtion: Gas Leakage Warning ");


  digitalWrite(GREEN, LOW);
  digitalWrite(RED, HIGH);
  digitalWrite(BUZZER_PIN, HIGH);
  digitalWrite(RelayPin, LOW);

```

```
  } else {
    Blynk.virtualWrite(V2, "Normal");
    Blynk.virtualWrite(V7, ratio);
    Blynk.virtualWrite(V1, 0);
    Blynk.virtualWrite(V3, 1);
    Blynk.virtualWrite(V4, 1);
    Blynk.virtualWrite(V5, 0);
    Blynk.virtualWrite(V6, 0);



    lcd.print("Normal");
    Serial.print("Condtion: Normal ");


    digitalWrite(GREEN, HIGH);
    digitalWrite(RED, LOW);
    digitalWrite(BUZZER_PIN, LOW);
    digitalWrite(RelayPin, HIGH);
  }

  delay(2000);
  lcd.clear();
}

```

Appendix B MQ2 Graph



Appendix C Gannt Chart PSM 2