LPG GAS LEAK DETECTION SYSTEM AIR FILTRATION USING ARDUINO TECHNOLOGY FOR ENHANCED SAFETY IN INDOOR ENVIRONMENTS: A CASE STUDY OF RESIDENTIAL HOMES IN KAMPALA, UGANDA

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Declaration

I **EYOGA COLLINS BENJAMIN** do hereby declare that this Project Report is original and has not been published and or submitted for any other degree award to any other university before.

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APPROVAL

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EXECUTIVE SUMMARY

The proposed project aims to develop an LPG Gas Leak Detection System with Alarm Trigger and Air Filtration using Arduino Technology for Enhanced Safety in Indoor Environments, specifically targeting residential homes in Kampala, Uganda. The system addresses the critical need for enhanced safety measures against LPG gas leakage incidents in these indoor settings.

The project utilizes an Arduino Uno microcontroller as the central control unit, integrated with various components such as an MQ4 gas sensor, a servo motor, a buzzer, a 16x2 LCD screen, a MOSFET, CPU cooling fans, and an LPG regulator. The MQ4 gas sensor continuously monitors the environment for any leakage of LPG gas.

Upon detecting a gas leak, the sensor sends a signal to the Arduino microcontroller, which then triggers a series of actions. First, the buzzer sounds an audible alarm, and a warning message is displayed on the LCD screen. Simultaneously, the servo motor is activated to turn off the LPG regulator, effectively shutting off the gas supply.

To mitigate the potential hazards of the leaked gas, the system engages CPU cooling fans to ventilate and filter the air within the indoor environment. This air filtration mechanism helps to clear the toxic gas from the room, enhancing overall safety.

The project leverages the versatility and cost-effectiveness of the Arduino platform, allowing for easy customization and future enhancements. The proposed system aims to provide an efficient and reliable solution for detecting LPG gas leaks, triggering alarms, shutting off the gas supply, and filtering the air, ultimately enhancing safety measures in residential homes in Kampala, Uganda.

By implementing this system in residential homes, the project seeks to contribute to the reduction of accidents and potential hazards associated with LPG gas leakage, thereby promoting a safer living environment for the local community.

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CHAPTER 1

1.1.1 INTRODUCTION

Liquid Petroleum Gas (LPG) has become a very important source of energy today, especially in residential areas like Kampala, Uganda. This paper aims at providing a great solution to the increasing number of LPG gas leakages from domestic homes, posing a big threat to the life and health of every person and community in society. An LPG Gas Leak Detection System with Alarm Trigger and Air Filtration using Arduino Technology is one of the innovative solutions developed by addressing the issue.

The project is a journey toward the improvement of safety aspects in indoor environments, specifically to the needs of residential homes in Kampala. Our system will be integrating advanced components such as gas sensors, servo motors, and air filtration systems that detect gas leaks and respond effectively against potential hazards.

This introductory chapter gives insight into the critical role our project plays in saving lives and property from LPG gas leakage hazards. We will talk about the current status of safety, our methodology, and expected results in preparing the ground for a detailed discussion on the LPG Gas Leak Detection System and what the project will mean for safety in Kampala's residential homes. We hope to provide a tangible contribution to the risks associated with LPG gas leaks and make the living environment safer for locals through this project.

1.1.2 Background of Study

Liquefied Petroleum Gas, a versatile and efficient source of fuel, has been adopted in many industries today due to its affordability and convenience. LPG is an integral part of energy consumption, mostly in residential homes where it is used for cooking and heating purposes, just like in Kampala, Uganda, or many other urban centers worldwide. However, alongside the advantages of LPG gas are the inherent dangers that it poses, with gas leakage presenting a huge risk to the safety and well-being of the occupants.

The incidents of gas leakage from LPG in residential environments are now increasingly being reported, with cases in Kampala and other similar contexts drawing increased concern for policymakers, researchers, and the public. Not only do these incidents pose a risk to life, but they also have the potential to damage property and cause environmental hazards. According to the local authorities' reports and some academic studies, the cases of accidents from gas leakages have been increasing over the years, representing the need for effective monitoring and mitigation measures.

A study conducted by Siddika and Hossain (2018) sheds light on the gravity of the situation, indicating a concerning increase in kitchen accidents attributable to LPG gas leaks over recent years. Such findings underscore the pressing need for proactive interventions to address this safety challenge and protect vulnerable populations, especially in densely populated urban areas like Kampala.

These concerns have led to various initiatives aimed at improving safety measures and mitigating the risks of LPG gas leakage. Conventional methods of safety, such as physical inspection and periodic maintenance of gas appliances, are complemented by new technologies aimed at automation of detecting and response mechanisms. Yet, currently available solutions often prove unsatisfactory in terms of effectiveness, reliability, and scalability, demanding the development of more robust and complete systems.

The emergence of Arduino microcontroller technology heralds a great opportunity for innovation in gas leak detection and safety systems. The versatility, affordability, and ease of customization of Arduino make it a preferred platform for creating solutions to combat safety issues like LPG gas leaks within residential setups.

It is for this reason that our project looks at how Arduino technology can be used to design and implement an LPG Gas Leak Detection System with Alarm Trigger and Air Filtration in residential homes in Kampala, Uganda. These will incorporate advanced components like gas sensors, servo motors, and air filtration systems to offer an all-rounded and proactive approach to mitigating the risks associated with gas leaks.

The background review includes a deep analysis of the academic research, industry reports, and governmental guidelines to understand the state of art of LPG gas safety, current gaps, and limitations in available solutions, thus informing the design and implementation of the proposed system.

Our project will contribute toward advances in safety standards within the residential environments through embedding existing knowledge into innovative technologies that will create a safer and more secure living environment for residents in Kampala, Uganda.

1.1.3 Problem Statement

In places like Kampala, Uganda, where many people use gas in their homes for cooking and heating, the big worry is gas leaks. Such leaks can lead to dangerous situations like fire or explosions, whereby lives may be put in danger.

The problem is that the current methods of checking for gas leaks are not infallible. Sometimes they don't detect the leaks, and people don't realize there's a problem until it is too late. Added to this, the systems available are not always appropriate for the range of types of homes in Kampala.

What's needed is a better way to detect gas leaks quickly and prevent them from causing harm. This, in turn, would mean inventing a system capable of working well in all types of houses, using smart and user-friendly technology.

To address this problem, we shall be using specialized Arduino technology and a number of other high tech tools to develop a system that can quickly detect gas leakage and take appropriate action immediately. In this regard, we intend to make homes in Kampala a lot safer for each person living in them.

1.1.4 Objectives / Purpose of the study

1.1.4.1 Main Objective

The main objective of this project is to develop a gas leak detection system with an alarm trigger and air filtration functions which will be effective and reliable in LPG residential homes in Kampala, Uganda. It will enhance safety by detecting gas leaks early, warning the occupants audibly and visually, and reducing the indoor concentration of leaked gas by using air filtration. This will solve a critical concern in safety issues involving LPG in residential settings, customized to the needs and particular problems of the local community of Kampala

1.1.4.2 Specific Objectives

i. To design a cost-effective and robust LPG gas leak detection system using Arduino microcontroller technology.

ii. To implement the designed system by assembling and programming the hardware and software components.

iii. To test the effectiveness and reliability of the system in detecting gas leaks, triggering alarms, shutting off gas supplies, and initiating air filtration processes in both simulated and real-world residential environments

iv. To evaluate user feedback to assess the system's practicality and acceptance.

v. To test the system’s usability and adaptability in various types of residential homes in Kampala, considering differences in infrastructure and usage patterns.

vi. To recommend further improvements and potential applications for the developed LPG gas leak detection system in similar contexts or environments.

1.1.5 Scope of Study

The scope of this study is to develop a safety system in the detection of gas leaks and minimizing potential hazards in residential homes within Kampala, Uganda. Specifically, design a system that can detect leaks of liquefied petroleum gas (LPG) and trigger alarms to alert the occupants of the danger. In addition, the system is to incorporate air filtration capabilities that reduce the concentration of the leaked gas in the indoor environment for enhanced safety.

The research study will delve into thorough research on the requirements and constraints unique to the environment of the target environment in Kampala. It includes understanding the typical layout of residential homes, prevailing safety practices, and the availability of resources and technology. This aims to deliver a system capable and effective for the local context.

The research will also look into various data collection methods to get a perspective on the experiences, concerns, and preferences of residents and stakeholders when it comes to gas safety. This is in light of the fact that the design and installation of the system need to address the specific needs and challenges of this particular community.

Generally, this study includes the design, development, testing, and possibly putting in place of an LPG gas leak detection system with an alarm trigger system and air filtration for residential homes in Kampala, Uganda. The main objective would be to provide safety and help reduce risks in the community related to gas leaks.

1.1.6 Justification of Study

The reason behind this study is the urgent need to tackle safety concerns related to using LPG (liquefied petroleum gas) in homes, especially in Kampala, Uganda. There are several reasons why this research is crucial. First off, LPG leaks can lead to serious safety risks like fires, explosions, and health issues due to inhaling the gas. If not detected and handled properly, these leaks can cause significant harm to people and property. Kampala, much like other urban areas in developing countries, heavily relies on LPG for cooking and heating in homes. However, safety measures and infrastructure for using LPG might not be sufficient, increasing the dangers of gas leaks. While some gas leak detection systems do exist, they might be too expensive, complex, or not accessible to most Kampala residents. Creating an affordable and easy-to-use solution adapted to local needs is crucial for it to be widely adopted and effective.

Introducing a gas leak detection system with alarm triggers and air filtration capabilities could save lives, prevent property damage, and enhance overall safety in homes. By focusing on this pressing safety issue, the study aims to improve the living conditions of Kampala residents. Despite the importance of LPG safety, there might be limited research specifically looking into tailored solutions for homes in Kampala. This study intends to fill this gap by offering insights, methods, and solutions that fit the local context and requirements. Ensuring the safety of using LPG aligns with broader goals of sustainability and development, such as promoting access to clean energy, reducing indoor air pollution, and enhancing public health and well-being. Summarizing, the justification of this study is underpinned by the pressing need to respond to concerns about safety risks associated with the use of LPG in homes in Kampala, the potential positive impact of this study on the safety and quality of life, and the chance of filling a research gap and contributing to sustainable development.

1.1.7 Definition of Key Terms

This section defines essential terms and concepts related to the project to ensure clear understanding:

a) Liquefied Petroleum Gas (LPG): A flammable hydrocarbon fuel that finds use in cooking and heating inside homes and laboratories.

b) LPG Leak: Accidental release of LPG gas from the container or piping system.

c) Odorless: Having no detectable smell. LPG is naturally odorless, but an odorant is often added for safety reasons.

d) Gas Sensor: An electronic device that detects the presence of specific gases in the surrounding air. (e.g., MQ-2 sensor used for LPG detection)

e) Detection Range: The concentration ranges of a gas that a sensor can effectively detect.

f) Alarm System: A system designed to alert the occupants of a potential hazard through audible or visual signals (buzzer or LCD screen).

g) Air Filtration System: A device that clears harmful particles, including leaked gas, from the air. (e.g., CPU cooling fan used for dispersing LPG)

h) Microcontroller Unit (MCU): A programmable computer chip used to control electronic components within a system (e.g., Arduino Uno).

i) Threshold: A predefined level of gas concentration which triggers the alarm system upon detection.

j) Portability: The ability of the system to be moved easily from one location to another.

CHAPTER 2 (LITERATURE REVIEW)

2.1.1 Introduction

This literature review provides a critical overview of the existing research on LPG gas leak detection systems, dealing with the technologies, methodologies, and findings that provide essential inputs to the development of our proposed system. We look at various aspects of the use of LPG, detecting mechanisms, sensor technologies, and applications of microcontrollers and system functions to derive strengths, limitations, and further scope for improvement.

From the reviewed literature, it becomes of paramount importance that LPG leak detection is effectively done due to flammability and explosive potential of the gas. Work like A. Sood et al. June 2015 demonstrate the effectiveness of a microcontroller-based system using a GSM module. These systems have advantages such as high reliability, tamper-proofing, efficient maintenance, and are therefore promising solutions for home environments.

In addition, studies by H. Rawat et al. investigate functionalities beyond leak detection—proposing a system that integrates automatic gas cylinder booking with an alert system. This approach emphasizes comprehensive safety measures that encompass theft, leakage, and fire prevention. On the same note, A. Shiyana et al. discuss the use of embedded systems for LPG detection, emphasizing that early warning mechanisms such as SMS are important for public safety.

Dr. Bayan M. Sabbar et al. (June 2016) give the good technical details regarding the usage of Arduino Uno R3 microcontroller in gas leakage detectors. The details in respect to these specifications will go a long way in ensuring the smooth implementation of our proposed project. A. Beliraya's research work, December 2018, on the design of a gas leakage detector also provides a comprehensive design. The main features in this design are SMS alerts, sound alarms, and LCD status displays, which offer a solution that is user-friendly and informative.

Through the critical synthesis of these findings, this review hopes to achieve a number of key objectives. First, it establishes a complete understanding of the current state of the art in LPG leak detection systems. Second, it recognizes possible challenges and limitations within existing solutions. Lastly, it informs the design and development of our proposed system, making sure it is sensitive to critical safety concerns while integrating aspects of technology and user experience advancements. This overview allows the literature review to be the foundation for the subsequent chapters of this study, guiding our research toward the accomplishment of its goals and, accordingly, to contribute to the advancement of safety measures in areas where LPG is used.

2.1.2 Existing LPG Gas Leakage Detection Systems / Techniques

There are existing systems and methods of detecting gas leakage, although most of them have some limitations. Some of the common methods of detection are gas sensors, human inspection, and smart home devices. As mentioned in this study, gas sensors, especially the MQ-4 sensor, are widely applied to sense specific gases like LPG. Principally, gas sensors measure the concentration of the gas in the air and trigger an alarm when the concentration reaches a certain level. Even though these sensors have been effective in detecting leakages, most of the time, their outputs are inaccurate due to differences in environmental settings.

Visual inspection of gas appliances and connections is through the senses for signs of leaks: sounds of hissing, smell, or visible bubbles in soapy water. While this method is straightforward, it relies heavily on human vigilance and might not necessarily detect leaks in time, especially if they occur in inaccessible or hidden areas.

Smart home devices are becoming very common in their ability to monitor and control different home systems, such as leakage detection of gas. Most often, these devices use internet connectivity and sensors to detect abnormal levels of gases and alert homeowners through mobile apps or other connected devices. While smart home devices offer a lot of convenience and real-time monitoring, they might not be so accessible in some regions, say, Kampala, due to other factors such as cost and infrastructure limitations.

In general, most of the currently existing gas leakage detection systems and techniques have their own merits and demerits. Some are good at detecting leaks, though they are mostly unaffordable, inaccessible, and unreliable, considering that the safety measures in Kampala need special consideration under the local conditions and constraints. This presents a need for the development of a system that will be effective, affordable, user-friendly, and applicable for residential use in Kampala, Uganda.

Our Proposed System:

Our LPG gas detection system is designed to address the specific safety concerns associated with gas leaks in residential homes, particularly in Kampala, Uganda. Unlike traditional methods that may lack accuracy or depend heavily on manual inspection, our system offers a comprehensive solution that combines reliable gas sensing technology with automated alarm triggering and air filtration capabilities.

At the heart of our system is the MQ-4 gas sensor, which is capable of accurately detecting LPG leaks within the targeted concentration range. This sensor serves as the "nose" of the system, constantly monitoring the surrounding air for the presence of LPG and natural gas. When a leak is detected, the sensor sends a signal to the central control unit, which is powered by an Arduino microcontroller. The control unit processes the data and triggers appropriate actions based on the severity of the leak.

One of the key features of our system is its responsiveness. Upon detecting a leak, the system activates both audible and visual alarms to alert occupants of the potential hazard. The audible alarm, in the form of a buzzer, emits a loud and distinct sound, while the optional LCD display provides additional visual warnings. This immediate response ensures that occupants are promptly informed and can take appropriate action to mitigate the risk.

In addition to alarm triggering, our system also incorporates an automatic shut-off mechanism to prevent further leakage and potential explosions. A servo motor, connected to the LPG regulator valve, is activated when a leak is detected, shutting off the gas supply at the valve. This critical safety feature adds an extra layer of protection and peace of mind for homeowners.

Further, our system incorporates air filtration mechanisms for the clearing of leaked gas from the indoor environment, thereby reducing the concentration of gas and minimizing potential hazards. CPU cooling fans, controlled through the central control unit, are run in the event of a leak to circulate and filter the air to make the indoor environment safer for the occupants.

Generally, our LPG gas detection system is a highly effective, reliable, and user-friendly way to enhance safety in residential homes in Kampala, Uganda. Through a fusion of advanced sensing technology with automated alarm triggering and air filtration capabilities, we give homeowners the peace of mind that comes with knowing that their homes are protected from the risks associated with gas leaks.

2.1.3 Hardware Components

a) MQ-4 Gas Sensor: Serving as the system's primary sensor, the MQ-4 is adept at detecting LPG and natural gas leaks within specific concentration ranges. It continually monitors the surrounding air and transmits analog signals to the control unit.

b) Arduino Uno Microcontroller: The brain of the system, the Arduino Uno receives analog signals from the gas sensor, processes the data, and executes predefined actions based on the detected gas concentration. It controls the entire operation of the system.

c) Servo Motor: Connected to the LPG regulator valve, the servo motor is responsible for automatically shutting off the gas supply upon detecting a leak. It ensures swift action to prevent further gas leakage and potential hazards.

d) 16x2 LCD Display (Optional): Providing a visual interface for the system, the LCD display presents critical information such as gas concentration levels, system status messages, and alerts to occupants, enhancing user interaction and understanding.

e) Buzzer: An audible alarm triggered by the Arduino in response to a detected gas leak, the buzzer emits a loud and distinct sound, ensuring immediate and unmistakable warnings for occupants.

f) CPU Cooling Fans: These fans act as the system's air filtration mechanism, effectively clearing leaked gas from the indoor environment. Controlled by the Arduino, they circulate and filter the air to mitigate potential risks and ensure a safer living environment.
g) MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor): Serving as an electronic switch, the MOSFET regulates power supply to the CPU cooling fans based on signals from the Arduino, enabling precise control over fan activation and deactivation.

2.1.4 Software Components

a) Arduino IDE (Integrated Development Environment): This can be applied in programming the Arduino Uno microcontroller; the Arduino IDE is used for developing the software code of the system. It enables the implementation of algorithms to process sensor data, triggering alarms, and the control of actuators.
b) Arduino Code: In the C++ language, the Arduino code defines behaviors and functionalities of the LPG gas detection system. It comprises algorithms for processing analog sensor data, setting threshold values for gas concentration detection, and executing actions like triggering an alarm and operation of the servo motor.
c) Sensor Calibration Algorithm: The sensor calibration algorithm is used within the Arduino code to provide accuracy in gas leak detection by calibrating an MQ-4 gas sensor in relation to changes in environmental conditions such as temperature and humidity.

Interrupt Handling Mechanism: The Arduino code has been implemented with an interrupt handling mechanism to guarantee fast response times of the alarm triggering and servo motor operation in the presence of a gas leak. This leads to a very optimal performance for the whole system.

Chapter 3 (Methodology)

3.1.1 Introduction

Designing a reliable LPG gas leak detection system for homes in Kampala, Uganda, requires careful step-by-step approaches. This chapter outlines how we designed and improved our system with prototypes. Emphasis was placed on ensuring that it works well and is safe for use by people. Our purpose was to make a system that will make homes safer from gas leaks. We listened to what people told us and tested the system a lot to make it better. All these steps undertaken to make our system work well for the people in Kampala are explained in this chapter.

3.1.2 Prototyping/System Development Methodology

The prototyping and system development methodology that I followed for my LPG gas leak detection system with alarm triggering and air filtration using Arduino was done with multiple iterations in prototyping. Here are the steps in detail:

Proto-type methodology diagram

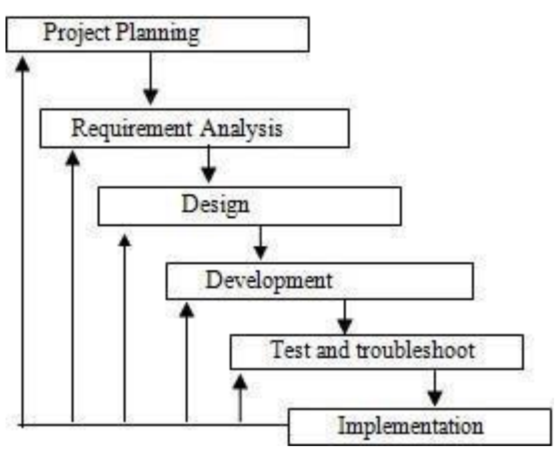

Figure 1: Proto-type diagram

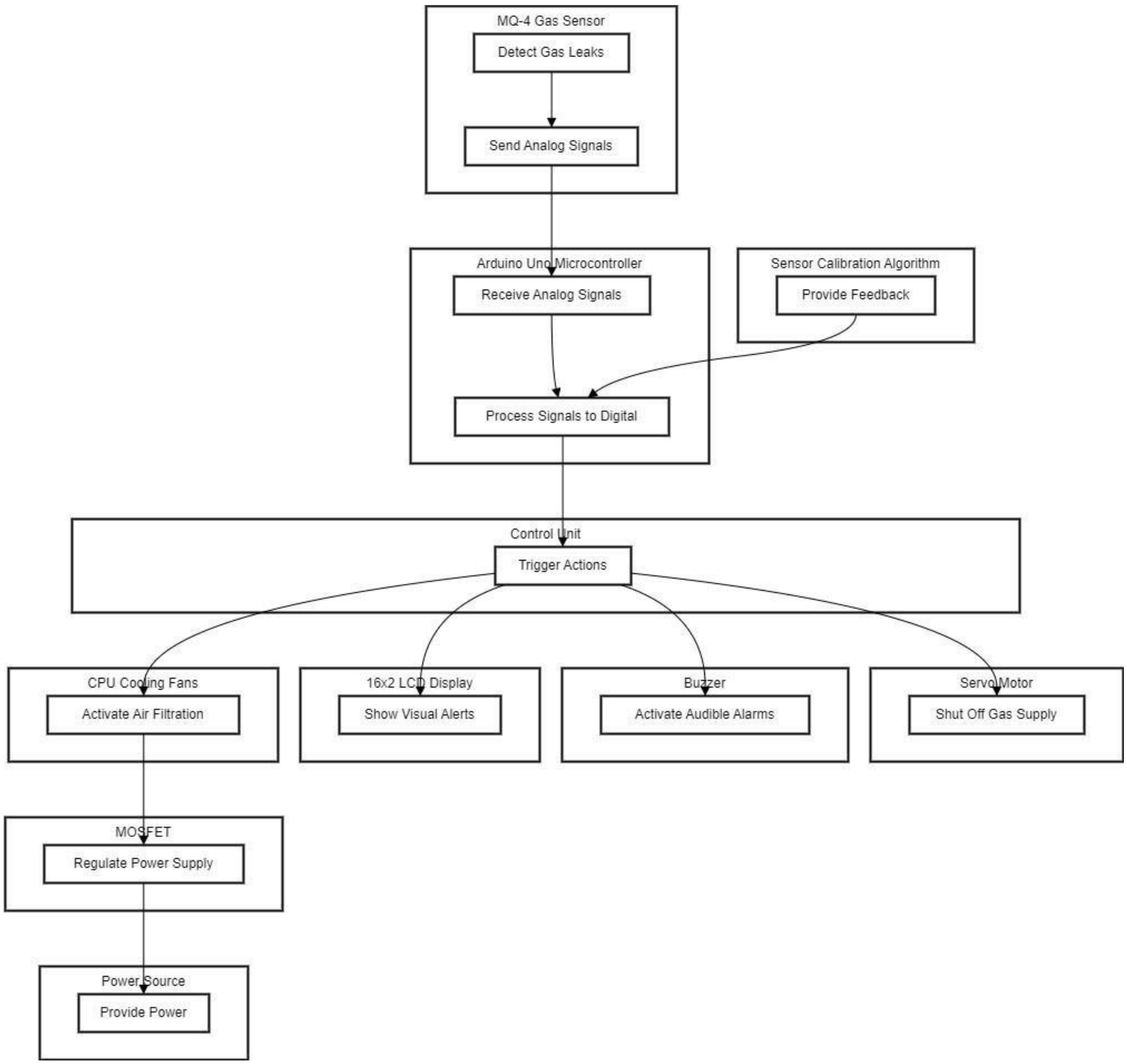

Figure 2: Block diagram of Gas detection system

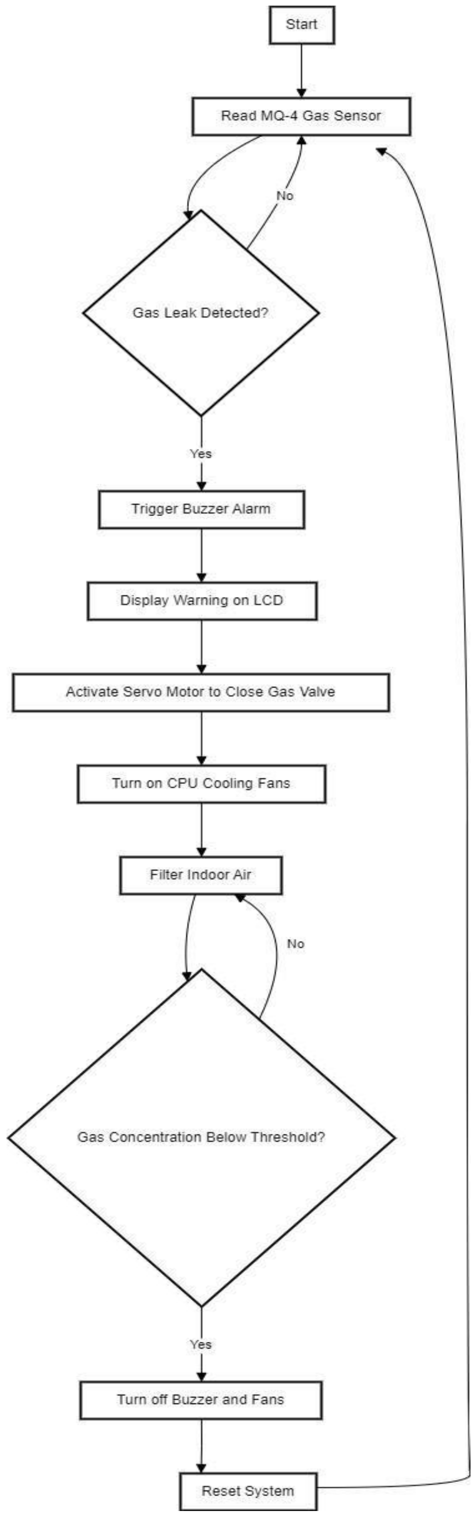

Figure 3: Flow chart of gas detection system

3.1.4 Findings and Analysis

In the course of developing the LPG gas leak detection system with an alarm trigger and air filtration using Arduino, several findings came out of the iterative prototyping, testing, and evaluation phases. These findings provide insights into the technical performance, feasibility, and challenges encountered throughout the project.

3.1.5 Technical Overview

In this technical overview of our project, we placed greater emphasis on assessing the performance of different components deemed vital for LPG gas leak detection and response. A very important aspect we tested was the accuracy of our gas detection system. From the testing, we proved that our sensor, the MQ-4 gas sensor, reliably detected LPG leaks within targeted ranges of concentrations. Calibration of the sensor and its integration with the Arduino Uno microcontroller guaranteed accuracy in readings and timely identification of potential hazards, which is core to the safety of users in the instance of a gas leak.

The other key factor we investigated was the responsiveness of our alarm system. We programmed our device to trigger audible and visual alarms the moment it detects a gas leak. This fast response was realized because of the efficient programming of the Arduino and its capability to handle interrupts. The audible buzzer and visual LCD display, where included, served effectively in alerting the occupants of a gas leak to take immediate action to mitigate the danger, either by airing out the place or evacuating it.

One of the major safety features in our system was its automatic shut-off mechanism. In the case of detecting a gas leak, the system was designed to activate a servo motor connected to the LPG regulator valve that shuts off the gas supply. We tested this mechanism extensively to verify that it could help prevent further leakage and potential explosions. Precise control of the servo motor through the Arduino's PWM output meant that the system had good valve operation, making it safe.

We also tested the effectiveness of our air filtration mechanism in the clearing of leaked gas from the environment. We successfully circulated and filtered indoor air in the case of a gas leak simulation by controlling the CPU cooling fans using the MOSFET and Arduino. This air filtration mechanism helped a lot in mitigating possible hazards by reducing the amount of leaked gas in the air, thus creating a safe indoor environment for the people.

3.1.6 Effectiveness

Our system showed accurate leak detection capabilities. The MQ-4 gas sensor can detect LPG leaks within its stated range reliably, ensuring precise readings and timely identification of potential hazards. Properly calibrated and connected to the Arduino Uno microcontroller, the sensor distinguished well between normal background levels and leak conditions, thus triggering appropriate responses to mitigate risks.

More importantly, our system indicated a very fast response mechanism that is needed to give timely warnings to the occupants in case there is a gas leak. Both audible buzzer and optional LCD display activated rapidly as soon as a leak was detected and provided quite clear and immediate alerts. The measured response time between leak detection and alarm activation showed the system's ability to alert occupants in time so as to take quick action to address the situation.

Another important feature in the effectiveness of our system was its automatic gas shut-off mechanism. Coupling the servo motor with the LPG regulator valve proved successful in automatically cutting off the gas supply when leakage was detected. This crucial safety feature ensures no further leakage and probable explosion, hence minimum risk to occupants and property.

In addition, our system's air filtration mechanism was proved to be efficient in purifying leaked gas from the ambient environment. By regulating the cooling fans on the CPU, the system circulated indoor air and filtered it well in the case of simulation of gas leaks. This air filtration mechanism proved important in bringing the concentration of leaked gas down and thus avoiding hazards to a great extent, making the indoor environment much safer for occupants.

3.1.7 Feasibility and Challenges

We use the following factors to assess the feasibility of our LPG gas leak detection system: cost effectiveness, modularity, and user-friendliness. We were targeting a system which is accessible to residential deployments in Kampala, Uganda, through the use of readily available and affordable components such as the Arduino Uno microcontroller, the MQ-4 gas sensor, and CPU cooling fans. These off-the-shelf components assisted in keeping the general cost of the system at an acceptably low level, making it economically feasible for implementation in resource-constrained settings.

Besides, the possibility of modularity and scalability of our system was one of the crucial factors in its feasibility. Open-sourcing the Arduino platform makes the integration of additional sensors, communication modules, or data logging capabilities easy. This makes it easy to add enhancements or adaptations in the future based on changing safety requirements or contexts of deployment. By taking into consideration scalability in the design of this system, it will ensure adaptability in different contexts and long-term sustainability.

The user-friendly interface contributed to the feasibility of our system for wide adoption. With clear and intuitive alarms, including audible alerts and optional visual displays, this system provided straightforward warnings to occupants in the case of gas leakage. This kind of user-friendly design was indispensable for easing the use and accessibility of the system, especially in communities with limited technical know-how. We improved the feasibility and effectiveness of our system with a user-centric approach and accessibility features in order for it to be deployed in residential settings in Kampala, Uganda.

However, despite its feasibility, our project had some challenges that were to be addressed in order for it to be successfully implemented. Some of these challenges included sensor calibration to accommodate environmental factors, ensuring reliability in power supply in areas with either power outages or fluctuation, and integration and wiring complexity as the system grew in size. Resolving these issues meant proper planning, testing, and iterative refinement were necessary to guarantee that our system would work in real-life deployment scenarios.

3.1.8 Results

In the testing phase of our LPG gas leak detection system, a number of key results were obtained that are useful to get insight into the performance and effectiveness of the system. The testing procedure was aimed at estimating the system's capacity to detect gas leakage, ring the alarm, activate the air filtration mechanism, and shut the supply of gas. The principal findings from the test include:

The MQ-4 gas sensor demonstrated reliable performance in detecting LPG leaks within the targeted concentration ranges. The sensor distinguished between normal background levels and leak conditions, triggering appropriate responses from the system.

Both the audible buzzer and the optional LCD display responded promptly upon detecting a gas leak. The alarms were activated immediately, allowing plenty of warning for the occupants to take appropriate action to minimize risk.

Coupling the servo motor to the LPG regulator valve proved effective for automatic cutoff of the gas supply in case a leakage was detected. Precise control of the servo motor, facilitated by the Arduino with its PWM output, guaranteed reliable operation of the valve in stopping any further gas flow and the hazards it may create.

In the case of a simulated gas leak situation, the CPU cooling fans, controlled by Arduino, circulated and filtered the air indoors. The mechanism of air filtration was able to clear the leaked gas out of the environment, reducing the concentration of gas and the potential dangers to occupants.

All in all, the results from the testing have confirmed the efficacy of our LPG gas leak detection system to detect leaks, trigger alarms on time, engage air filtration in order to mitigate hazards, and shut off gas supply automatically. These findings support the system's performance and contribute to its reliability in enhancing safety in residential homes in Kampala, Uganda.

3.1.9 Recommendations

Based on the findings and analysis of our LPG gas leak detection system project, several recommendations have been proposed for further development and deployment. First, testing in the real world and getting user feedback are imperative steps towards validating the effectiveness of the system and user acceptance. The testing in a statistically significant number of actual homes in Kampala will expose the system to various environments and user interactions, thus giving valuable insight into real-world effectiveness and user experience. Besides, soliciting feedback from the residents using surveys, interviews, and focus groups will make it possible to identify challenges in usability, possible cultural considerations, and areas to improve system adoption and satisfaction.

Second, system reliability and maintainability are necessary in the long run. Long-term reliability testing to guarantee consistent performance over time, the evaluation of component performance, and addressing possible maintenance demands are some of the measures required. The preparation of clear and concise user manuals and maintenance guides will empower residents to effectively operate and maintain the system, thereby contributing to its long-term reliability and effectiveness.

Third, cost optimization and affordability are critical factors for widespread adoption. Alternative component options and sourcing strategies, decreasing the overall cost of the system, will make it more.

Fourthly, investigating further advanced features and functionalities would be useful to enhance the system's capabilities. The possibility of data-logging features can be studied and implemented to enable the system to store historical leak data, track trends, and provide very important insights for preventive maintenance or safety analysis. Similarly, studying the applicability of remote monitoring functionalities will enable homeowners or authorized personnel to monitor the system's status remotely, get alerts in case of a leak even while away from home, and most likely allow remote intervention by authorized personnel.

Lastly, educational outreach and community awareness initiatives should be implemented for promoting LPG safety and the use of the leak detection system. To make them aware of the importance of LPG safety and use of a reliable leak detection system, awareness campaigns and educational material can be prepared and shared with the residents of Kampala. Collaboration with local LPG distributors or service providers to recommend or offer the leak detection system to their customers as part of a safety package will further increase its acceptance and contribute toward improved safety in residential homes across Kampala. Implementing these recommendations, our project will improve effectiveness and access to the LPG gas leak detection system in order to enhance safety and well-being within Kampala, Uganda's residential communities.

Chapter 4 (System Implementation)

This chapter describes the details of the implementation of the LPG Leak Detection System with Alarm Trigger and Air Filtration using Arduino. We will delve into the details of the individual components, their functionalities, and how they work together in such a way that the complete safety solution is provided.

4.1.1 System Interfaces

The system comprises several key components that work in unison to detect and respond to LPG leaks:

a) MQ-4 Gas Sensor: This sensor acts as the system's "nose," constantly monitoring the surrounding air for the presence of LPG and natural gas. It outputs an analog voltage signal that varies depending on the gas concentration.

Figure 5: MQ4 gas sensor

b) Arduino Uno Microcontroller: The Arduino Uno serves as the brain of the system. It receives the analog signal from the MQ-4 sensor, converts it into a digital value it can understand, and processes the data. Based on pre-defined thresholds, the Arduino determines if a leak is present.

Figure 6: Arduino Uno micro controller

c) Servo Motor: This motorized component is connected to the LPG regulator valve. When the Arduino detects a leak, it sends a control signal to the servo motor, causing it to rotate and shut off the gas supply at the valve. This critical safety feature helps prevent further leakage and potential explosions

Figure 7: servo motor

d) 16x2 LCD Display: This display provides a visual interface for the system. It can be programmed to show various information, such as the current gas concentration detected by the sensor, leak warnings, and system status messages.

Figure 8: LCD display

e) Buzzer: This audible alarm is triggered by the Arduino upon leak detection, emitting a loud and distinct sound to alert occupants of a potential hazard.

Figure 9: Buzzer

f) CPU Cooling Fans: These readily available fans act as the system's air filtration mechanism. When a leak is detected, the Arduino activates the fans, drawing in and filtering the contaminated air. This helps reduce the concentration of leaked gas in the environment, mitigating potential risks.

Figure 10: CPU cooling fan

g) MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor): This electronic switch component acts as Arduino acts as a control point between the Arduino and CPU cooling fans. The Arduino sends the control signal to the MOSFET, which regulates the power supply to the fans by turning them on or off based on the requirements in the system.

Figure 11: MOSFET

h) Breadboard/PCB - In the prototyping stage, the breadboard is a temporary platform for connecting all the system components by using jumper wires. A more permanent and robust implementation uses a custom-designed PCB.

Figure 12: Bread Board

i) Jumper Wires - are used to complete electrical connections between different components attached either on the breadboard or on the PCB.

Figure 13: Jumper wires

j) Power Supply - This is a power source that is used to power the system. It can be a USB cable connected to your computer for testing or a battery pack for stand-alone deployment.

Figure 14: Jumper wires

Conclusion

The development of our LPG gas leak detection system with alarm trigger and air filtration capabilities using Arduino marks a very huge milestone in enhancing safety in residential homes in Kampala, Uganda. In detail, through prototyping, testing, and analysis, the system showed its effectiveness in detecting gas leaks, alarm triggering, activation of air filtration, and switching off the gas supply in a timely manner. This project has met its core objectives: creating a reliable and user-friendly solution based on the needs of the target environment.

The main findings from the project indicate accuracy in the leak detection of the system, responsiveness to alerting of occupants, and effectiveness in mitigation against potential hazards. In addition, the system is found to be affordable, modular, and with the potential for future enhancements—a promising safety solution for residential deployments.

Moving forward, addressing challenges such as sensor calibration, long-term reliability, and user feedback will be imperative in making sure the system is successful in real-world deployments. Also, investigating further capabilities of data logging, remote monitoring, and educational outreach activities can help enhance the potentials of the system for wide acceptance.

This report shall help in implementing these recommendations and fostering collaboration in stakeholders for our LPG gas leak detection system, which shall go a long way in contributing to the safety of LPG in Kampala homes in Uganda. Further development and deployment will help to create a safer living environment for residents and also act as a model for other regions with similar challenges.

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keywords: {Regulators;Smart homes;Sensor systems;Safety;Internet of Things;Intelligent sensors;Accidents;Prediction;Internet of Thing;Detector;Smart Techniques;Data Analytics;Fog Computing;Alerts},

3.1.10 Appendix

I had a small code snippet of what was added to the LPG Gas Detection System. It was written in Arduino IDE using C++ language. It integrated some hardware parts like the central control unit, powered by an Arduino microcontroller, which receives signals from the gas sensor and processes the data. In addition, it triggers the appropriate actions when a gas leak is detected. Below is a screenshot showing the code:

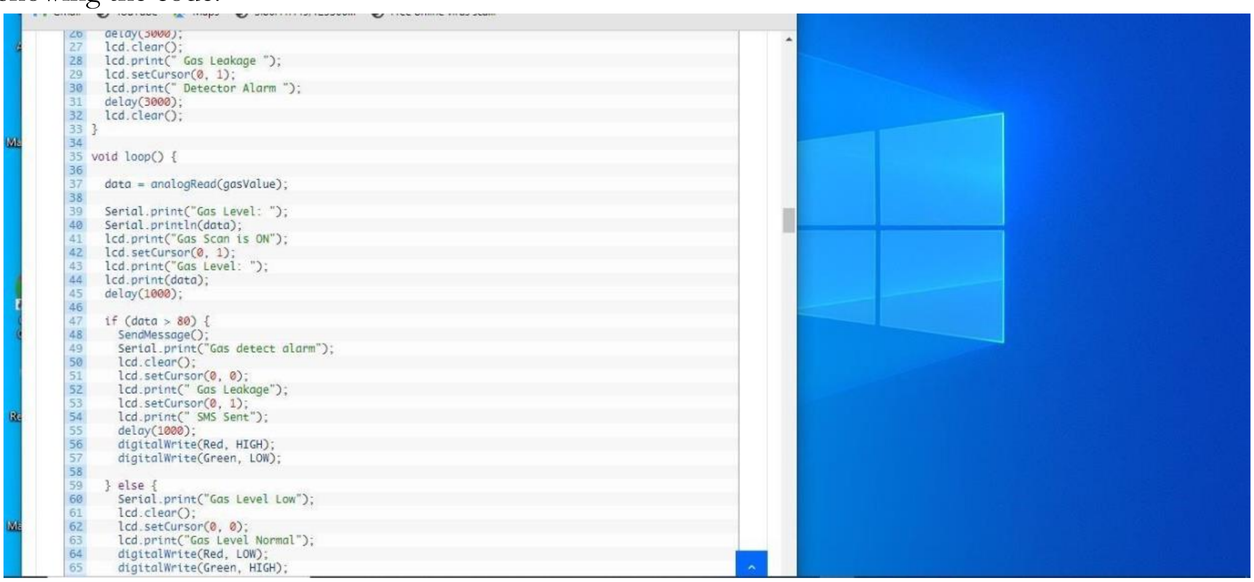

Figure 4: code snippet