DESIGN AND DEVELOPMENT OF A SMART GAS LEAKAGE DETECTION, MONITORING AND MULTISTAGE PREVENTION SYSTEM USING IOT

A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science in Mechanical Engineering



By

MD. IMRAN ALI

13MME012P

Supervised by

DR. JAMAL UDDIN AHAMED

Professor, Dept. of ME, CUET

APPROVAL

The thesis titled "**DESIGN AND DEVELOPMENT OF A SMART GAS LEAKAGE DETECTION, MONITORING AND MULTISTAGE PREVENTION SYSTEM USING IOT**" submitted by Md. Imran Ali (ID:13MME012P) has been accepted as satisfactory by the dissertation committee for the partial fulfillment of the requirement for the degree of master of science (M.Sc.) in Mechanical Engineering, dated on 19th June 2025.

Dissertation Committee

Dr. Jamal Uddin Ahamed Professor, Department of Mechanical Engineering, CUET.	Chairman (Supervisor)
Dr. Prasanjit Das Professor, Department of Mechanical Engineering, CUET.	Member (Co-Supervisor)
Dr. Muhammad Mostafa Kamal Bhuiya Head, Department of Mechanical Engineering, CUET.	Member (Ex Officio)
Dr. Kazi Afzalur Rahman Professor, Department of Mechanical Engineering, CUET.	Member
Dr. Abu Shadat Muhammad Sayem Professor, Department of Mechanical Engineering, CUET.	Member
Dr. Mohammad Asaduzzaman Chowdhury Professor, Department of Mechanical Engineering, DUET.	Member External

Declaration

I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by another person, or material which to a substantial extent has been accepted for an award of any degree or diploma at this or any other higher education institution. So far as I am aware, there is no material in the thesis that has been published or that is written by another person except where due acknowledgement is made. Also, the thesis complies with Plagiarism and Academic Integrity policy of CUET.

Md. Imran Ali
(ID:13MME012P)
Department of Mechanical Engineering
Chittagong University of Engineering & Technology (CUET)

Copyright © Md. Imran Ali, 2025
This work may not be copied without permission of the author or
Chittagong University of Engineering & Technology.

Approval by the Supervisor and Co-supervisor

This is to certify that Md. Imran Ali (ID:13MME012P) has carried out this work under my supervision and that he has fulfilled the relevant academic ordinance of the Chittagong University of Engineering and Technology so that he is qualified to submit the following thesis in application for the degree of master of science in mechanical engineering. Furthermore, the thesis compiles with plagiarism and academic integrity regulation of CUET.

Dr. Jamal Uddin Ahamed
Professor
Department of Mechanical Engineering
Chittagong University of Engineering & Technology

Dr. Prasanjit Das
Professor
Department of Mechanical Engineering
Chittagong University of Engineering & Technology

Abstract

The widespread use of natural gas and liquified petroleum gas (LPG) has raised significant safety concerns, as leaks from cylinders or pipelines can lead to catastrophic fires, explosions, loss of life, property damage, and economic losses. With increasingly busy lifestyles, many individuals pay insufficient attention to gas-related safety at home. To address this issue, we have developed a smart gas leakage detection, monitoring, and multistage prevention system that ensures safety through automation and real-time control. This intelligent system continuously monitors gas levels using high-sensitivity sensors. Upon detecting a leak, it immediately alerts the user via an IoT-enabled Android application. Simultaneously, it activates a servo motor to shut off the gas valve, turns on the exhaust fan to disperse the gas, and triggers a buzzer to warn occupants. In cases of severe leakage, the system goes further by automatically cutting off the home's electric power to prevent ignition and sending emergency short message service (SMS) or email notifications to the nearest fire service for rapid response. A load cell is also integrated to track the LPG cylinder's weight in real-time, allowing users to monitor gas levels and plan refills in advance. Additionally, an automatic shut-off regulator adds another layer of safety by instantly halting gas flow in the event of pipe bursts or regulator failures. Designed for both residential and commercial use, the system combines safety, reliability, and user convenience. With an estimated 98% accuracy in shut-off operations, it offers a comprehensive solution for preventing gas-related accidents, thereby ensuring peace of mind and significantly reducing the risk of disaster.

সার-সংক্ষেপ

প্রাকৃতিক গ্যাস এবং তরলীকৃত পেট্রোলিয়াম গ্যাস (এলপিজি)-এর ব্যাপক ব্যবহার নিরাপত্তাজনিত গুরুতর উদ্বেগের সৃষ্টি করেছে, কারণ সিলিন্ডার বা পাইপলাইনের গ্যাস লিকের কারণে বিধ্বংসী অগ্নিকাণ্ড, বিস্ফোরণ, প্রাণহানি, সম্পদের ক্ষতি এবং অর্থনৈতিক ক্ষতির মতো বিপর্যয় ঘটতে পারে। বর্তমান ব্যস্ত জীবনে অনেকেই বাসার গ্যাস দূর্ঘটনা হতে নিরাপত্তার বিষয়ে যথেষ্ট মনোযোগ দিতে পারেন না। এই সমস্যার সমাধানে আমরা একটি স্মার্ট গ্যাস লিকেজ শনাক্তকরণ, পর্যবেক্ষণ এবং বহুস্তর নিরাপত্তা প্রতিরোধ ব্যবস্থা তৈরি করেছি, যা স্বয়ক্রিয়তা ও রিয়েল-টাইম নিয়ন্ত্রণের মাধ্যমে নিরাপত্তা নিশ্চিত করে। এই বুদ্ধিমান সিস্টেমটি উচ্চ-সংবেদনশীল সেন্সরের মাধ্যমে গ্যাসের মাত্রা সার্বক্ষণিক পর্যবেক্ষণ করবে। গ্যাস লিক শনাক্ত হওয়ার সঙ্গে সঙ্গে, এটি একটি IoT (ইন্টারনেট অফ থিংকস) সক্ষম অ্যান্ড্রয়েড অ্যাপের মাধ্যমে ব্যবহারকারীকে সতর্ক করে। একই সাথে, এটি একটি সার্ভো মোটর চালু করে গ্যাস ভাল্ভ বন্ধ করে দেয়, এগজস্ট ফ্যান চালু করে লিকেজ গ্যাস বের করে দিতে সহায়তা করে এবং বাসার লোকজনকে সতর্ক করার জন্য একটি বাজার (বিপ সংকেত) চালু করে। গুরুতর গ্যাস লিকেজের ক্ষেত্রে সিস্টেমটি আরও একধাপ এগিয়ে গিয়ে স্বয়ংক্রিয়ভাবে ঘরের বৈদ্যুতিক সংযোগ বিচ্ছিন্ন করে দেয় যাতে আগুন লাগার ঝুঁকি কমে এবং কাছাকাছি ফায়ার সার্ভিসে জরুরি এসএমএস বা ইমেইল পাঠিয়ে দ্রুত প্রতিক্রিয়া নিশ্চিত করে। এছাড়াও এতে একটি লোড সেল যুক্ত করা হয়েছে, যা এলপিজি সিলিন্ডারের ওজন রিয়েল-টাইমে পর্যবেক্ষণ করে, ফলে ব্যবহারকারীরা গ্যাসের পরিমাণ জানতে পারেন এবং অগ্রিম রিফিলের পরিকল্পনা করতে পারেন। একটি স্বয়ংক্রিয় শাট-অফ রেগুলেটরও যুক্ত করা হয়েছে, যা পাইপ ফেটে যাওয়া বা রেগুলেটরের ত্রুটির সময় সঙ্গে সঙ্গে গ্যাসের প্রবাহ বন্ধ করে দেয়, নিরাপত্তার আরেকটি স্তর যোগ করে। বাসা ও ব্যবসায়িক ব্যবহারের জন্য ডিজাইনকৃত এই সিস্টেমটি নিরাপত্তা, নির্ভরযোগ্যতার সহিত ব্যবহার করা যাবে। আনুমানিক ৯৮% নির্ভুল ভাবে শাট-অফ কার্যকারিতার মাধ্যমে এটি গ্যাস সংক্রান্ত দুর্ঘটনা প্রতিরোধে একটি পূর্ণাঙ্গ সমাধান দেয়, যার ফলে ব্যবহারকারীর মানসিক শান্তি নিশ্চিত হয় এবং বিপর্যয়ের ঝুঁকি উল্লেখযোগ্যভাবে কমে যায়।

Acknowledgement

Above all, I would like to express my gratitude to my supervisor, Dr. Jamal Uddin Ahamed, Professor, Dept. of ME, CUET for accepting me into his research group and also express my heartfelt thanks to him for his guidance, encouragement, and continuous support during my project work. His enthusiasm for teaching and research offered me challenging opportunities to expand my scientific knowledge and my growing interest in the Automation system specifically using of IOT based system.

Veritably, Indebted to my co-supervisor Dr. Prasanjit Das, Preofessor, Department of Mechanical Engineering, Chittagong university of Engineering and Technology. For Everything he had done to help in this thesis. I will remain obliged for sharing of time and knowledge to this thesis.

Also, I would like to express special thanks to Dr. Muhammad Mostafa Kamal Bhuiya, Preofessor and Head, Department of Mechanical Engineering, Chittagong university of Engineering and Technology for administrative support and help in regarding this thesis. Finally, I would like to express sincere thanks to all of my respected teachers of the Department of Mechanical Engineering, Chittagong university of Engineering and Technology for their inspiration, overall guidance and opinion in this regard.

Table of Contents

APPROVAL ii
Declaration iii
Approval by the Supervisor and Co-supervisor iv
Abstract v
সার-সংক্ষেপ vi
LIST OF FIGURES x
LIST OF TABLES xii
LIST OF SYMBOLS AND ABBREVIATIONS xiii
Chapter 01 1
Introduction 1
1.1 Background and motivation 1
1.1.1 Problem Statement 3
1.2 LPG Production Systems and properties of LPG 5
1.2.1 Types of LPG Production Systems 6
1.4 Physical and chemical properties of LPG 8
1.5 Comparison of the physical properties of natural gas vs LPG 10
1.6 LEL and UEL of LPG and natural gas 11
1.7.1 Recent Fire Incidents due to gas leakages 14
1.8 Statistics of Fire Incidents from line Gas and LPG Cylinder 18
1.8.1 Annual report (2017-2023) of Accident According to Bangladesh Fire Service and Civil Defense 19
1.8.2 Another Method to Detect Leaked In Pipeline Gas By Adding Odorant 22
1.9 The Role of IoT in Enhancing LPG Safety 22
1.10 Future of IoT 24
1.11 Outline of the Thesis 25
Chapter 02 27
Literature Review 27
2.1 Introduction 27
2.2 Previous related studies 27
2.3 Conclusion 38
Chapter 03 39
Methodology 39
3.1 Introduction 39
3.2 System Workflow 39
3.2.1 Monitoring Stage 39
3.2.2 Detection Stage 40

3.2.3 Prevention Stage 40
3.2.4 Visualization Stage 41
3.2.5 Overall System Coordination 44
3.2.6 Protection from sudden major gas leakage using auto shut-off valve/device 44
3.2.7 Key Components of auto shut-off valve: 47
3.3 Hardware Design and Components 49
3.3.1 Microcontroller (ESP8266) 50
3.3.2 Gas Sensor (MQ6): 50
3.3.3 Servo Motor 51
3.3.4 Exhaust Fan 52
3.3.5 Weight Measurement System (Load Cell) 53
3.3.6 Power Supply 53
3.4 Software Design and Components 53
3.4.1 IoT Integration (Blynk App) 54
3.4.2 Programming 56
3.5 Electrical Simulation (Proteus) 57
3.5.1 Gas Leakage Simulation 57
3.5.2 Load Cell Simulation 58
3.5.3 Alert Testing 58
3.6 Conclusion 58
Chapter 04 60
Results and Discussion 60
4.1 Introduction 60
4.2 Implementation of gas leakage detection system 60
4.3 Implementation of LPG cylinder weight monitoring system and overall integrated system 65
4.5 Cost Analysis 68
4.5 Comparison Between Marketed Auto Shut Off Device Vs Proposed System 69
4.6 Discussion 73
4.7 Conclusion 76
Chapter 05 77
Conclusion and Recommendations 77
5.1 Introduction 77
5.2 Summary of findings 77
5.3 Summary: 78
5.4 Recommendations: 79
References 80

LIST OF FIGURES

Fig. 1. 1: Fractional Ditillation Column [4]. 7
Fig. 1. 2: Route of LPG from production to the end-consumer [1] 8
Fig. 1. 3: LEL and UEL of Methane [91]. 12
Fig. 1. 4: LEL and UEL of Propane[91]. 13
Fig. 1. 5: CNG stations blast due to leakage of pipe line gas at Mymensingh city, 4 November, 2024. 15
Fig. 1. 6: Gas cylinder explosion at Dhamrai CNG station on 18 October 2024. 16
Fig. 1. 7: Gazipur LPG cylinder blast on 13 march, 2024. 16
Fig. 1. 8: Gas cylinder explosion of the devastating fire at the Green Cozy Cottage on Dhaka's Bailey Road on 29th Feb 2024. 17
Fig. 1. 9: Accident due to LPG leakage in 2018, Joypurhat 17
Fig. 1. 10: Fire Incident Due to Cylinder gas Leakage. 18
Fig. 1. 11: Statistics of fire incident from line gas and LPG cylinder (2017-2023) ... 20
Fig. 3. 1: Block Diagram of gas leakage detection, monitoring and multistage prevention system 42
Fig. 3. 2: Flowchart of the proposed smart gas leakage detection, monitoring and multistage prevention system 43
Fig. 3. 3: Inside view of lpg Cylinder. 45
Fig. 3. 4: Flow diagram of using auto shut-off valve 46
Fig. 3. 5: Performance chart of marketed Auto shut off device 47
Fig. 3. 6: Using auto shut-off valve/device (Real Device). 48
Fig. 3. 7: Arrangement for cut- off pressure measure of Auto shut off device. 48
Fig. 3. 8: Microcontroller (ESP8266). 48
Fig. 3. 9: Gas Sensor (MQ6) 48
Fig. 3. 10: Photograph of Servo Motor 50
Fig. 3. 11: Integration of the whole circuit in Proteus. 51
Fig. 3. 12: Monitoring and controlling by using IOT [102] 52
Fig. 4. 1: Arrangement of gas leakage detection system 61
Fig. 4. 2: Implemented Blynk Dashboard (Website) 62
Fig. 4. 3: Implemented Blynk Dashboard (Mobile) 62
Fig. 4. 4: Email alert notification 63

Fig. 4. 5: Gas dissipation over time 64
Fig. 4. 6: Overall Integrated System 64
Fig. 4.7: Simulation of the whole system in proteus..... 65
Fig. 4. 8: Marketed auto shut-off device..... 69
Fig. 4. 9: Auto Shut-off PPM level of marketed Auto shut off device 71
Fig. 4. 10: Comparison of Auto shut off level between Proposed system vs Marketed device 72

LIST OF TABLES

Table 1. 1: Crude oil Composition by weight [3] 7
Table 1. 2: Properties of LPG [5]..... 9
Table 1. 3: Properties of Natural Gas Vs LPG [6]. 10
Table 1. 4: Gas concentration Unit [6]..... 13
Table 1. 5: Annual report of Bangladesh Fire Service and Civil Defense. 20
Table 1. 6: Causes of leakage form LPG Cylinder and pipeline gas [92][97]. 21
Table 3.1: Cut-off Pressure Measurements of auto shut-off device (in mm of water &ml bar)…… ……. 49
Table 4. 1: Measured weight vs actual weight. 66
Table 4. 2: Mathematical Calculation. 66
Table 4. 3: Load cell Performance Matrix. 67
Table 4.4 Uncertainty Analysis,…… 67
Table 4. 5: Illustration of costing……..69
Table 4. 6: Comparison Data Table 72
Table 4.7: Multistage Prevention approach…… 74

LIST OF SYMBOLS AND ABBREVIATIONS

ABBREVIATIONS

LPG	Liquefied Petroleum Gas
NG	Natural gas
IoT	Internet of Things
LEL	Lower Explosive Limit
UEL	Upper Explosive Limit
MMSCF	Million standard cubic feet
PRV	Pressure Relief valve
PPM	Parts per million.
MQTT	Message Queuing Telemetry Transpor

Chapter 01

Introduction

1.1 Background and motivation

Natural gas and liquefied petroleum gas (LPG) are among the most widely used fossil fuels globally, including in Bangladesh due to their high energy efficiency, portability, and relatively low environmental impact. They are commonly used for cooking and heating in households, restaurants, hotels, and various industrial and commercial establishments. The rapid depletion of natural gas reserve and the growing global demand for cleaner and more efficient energy sources have brought Liquefied Petroleum Gas (LPG) to the forefront as a viable alternative fuel. As a byproduct of natural gas processing and crude oil refining, LPG is composed of propane and butane, offering high energy efficiency, portability, and greater environmental friendliness compared to traditional fuels. Its versatility has made it indispensable across domestic, industrial, automotive, and agricultural sectors. The increasing reliance on natural gas and liquefied petroleum gas (LPG) for domestic and industrial purposes has significantly transformed modern life by providing an efficient and relatively clean source of energy. These gases are widely used for cooking, heating, industrial processing, and more due to their affordability, high calorific value, and convenience. The volatile and flammable nature of these gases poses a serious safety risk. Any leakage whether from pipelines, valves, or cylinders can lead to devastating fires, explosions, environmental hazards, property damage, injuries, and even loss of life. Traditional gas safety measures are often manual, reactive, or limited in their scope. In many households, gas leak detection relies on human senses such as smell or hearing or on outdated detectors that only sound alarms without taking any further action. These conventional systems lack the ability to provide early warnings, remote alerts, real-time data monitoring, or automated preventive control, which are critical in minimizing potential damage during gas leak incidents.

The evolution of Internet of Things (IoT) technology offers a promising avenue for addressing these challenges. By embedding sensors, microcontrollers, wireless communication modules, and cloud-based services, IoT enables the creation of smart, connected systems that can monitor, analyze, and respond to real-time gas leakage events. When implemented effectively an IoT-based gas safety system can not only detect a leak but also automatically activate preventive actions (such as turning off gas valves, activating exhaust fans, sending mobile notifications, or alerting emergency services), thereby significantly enhancing the safety and reliability of gas usage in both residential and industrial environments. The motivation behind this project stems from a combination of personal safety concerns, technological opportunity, and societal need:

1. Rising incidents of gas accidents**:** In many parts of the world including Bangladesh there have been numerous reported cases of gas explosions resulting from undetected leaks. These incidents often lead to fatalities and major property loss. The lack of affordable, effective, and accessible gas safety systems has left many households and businesses vulnerable.
2. Inadequacy of traditional system: Most gas leakage detectors available in the market provide only a basic alert (usually an audible alarm), with no automatic response mechanism. These systems often fail if the user is not present or unable to respond immediately. This limitation increases the risk of delayed intervention and catastrophic consequences.
3. Potential of IOT-based automation**:** With the growing penetration of IoT devices and low-cost microcontrollers (like Arduino, ESP8266, or NodeMCU), it is now feasible to design systems that are cost-effective, scalable, and customizable. IoT enables remote monitoring, data logging, real-time notifications, voice control (e.g., Alexa, Google Assistant), and intelligent automation, which makes it ideal for building an advanced safety mechanism.
4. Personal and community safety awarness: To develop this system we inspired by a desire to contribute to safer living environments especially in densely populated urban areas where gas usage is high and emergency response times are often delayed. This system is envisioned not just as a product, but as a preventive public safety tool.

5. Research and Innovation potential: The integration of sensors, IoT, AI-based decision-making, and cloud technologies into safety systems is still an emerging field. This project offers an excellent opportunity to explore new methods of multistage prevention, such as combining gas detection with automatic fan activation, electric cut-off, and intelligent user alerts. The research contributes to the development of smart homes and smart cities, aligning with global trends toward automation and safety.

1.1.1 Problem Statement

In Bangladesh and other developing country the adoption of LPG has surged due to urbanization, reduce availability of traditional fuels like firewood and the pursuit of cleaner cooking alternatives. Households, industries and even transportation systems now depend on LPG. The government and private sectors have invested in LPG infrastructure to support this growing demand recognizing its potential to reduce indoor air pollution, improve health outcomes and lower greenhouse gas emissions. However, alongside these benefits, the risks associated with LPG particularly gas leaks, explosions and fire hazards pose critical safety concerns. Historically, numerous incidents have highlighted the devastating consequences of mishandling LPG. Explosions caused by cylinder leaks, faulty regulators, or improper installations have resulted in property damage, injuries, and loss of life, highlighting the urgent need for robust safety mechanisms. Gas explosion tragedies around the world have emphasized the necessity of proactive measures to prevent leaks and minimize the risks associated with this highly flammable fuel. Over the years, countless gas-related accidents have been reported globally, often due to undetected leaks from cylinders, pipelines, or regulators. In many cases, the root causes include poor-quality equipment, aging infrastructure, improper installations, lack of maintenance, and human error. For example, a small undetected leak in a confined space can quickly turn into a catastrophic event if the gas accumulates and finds an ignition source. Historical tragedies in both urban and rural settings underscore the urgent need for effective and automated safety systems to address these risks proactively.

Conventional gas leakage detectors available in the market typically operate using simple gas sensors that trigger a local audible alarm when the gas concentration exceeds a certain threshold. These systems often lack intelligence, connectivity, or automation, making them ineffective in situations where the user is not physically present or unable to act quickly. Furthermore, they do not support remote alerts, integration with smart devices, or

automatic shutoff mechanisms, which are crucial for comprehensive safety assurance. In today's fast-paced lifestyle, people are often not present at home or workplaces to respond promptly to gas leak warnings. This gap between detection and response significantly increases the potential for accidents. In addition, there is a lack of public awareness and preparedness when it comes to managing gas-related emergencies. As urbanization increases and more households rely on LPG for daily activities, the scale of risk continues to grow. With the advancement of Internet of Things (IoT) technologies, there exists a significant opportunity to create smart, connected, and automated systems that can overcome the limitations of traditional gas detectors. By integrating real-time monitoring, wireless communication, mobile alerts, and multistage prevention mechanisms (such as activating exhaust fans, turning off solenoid gas valves, and sending emergency notifications), an IoT-based solution can offer a far more effective and reliable safety net.

The scientific community has increasingly turned to technology, particularly the Internet of Things (IoT) to address these challenges. IoT-enabled systems offer a comprehensive solution by combining sensors, controllers and real-time communication platforms to monitor and manage LPG safety. Sensors such as MQ-2 and MQ-6 detect gas leaks by measuring LPG concentration levels in the air, while microcontrollers like NodeMCU and Arduino process this data to trigger alarms, send notifications and activate preventive mechanisms such as shutting off gas supply valves or operating exhaust fans. These advancements can drastically reduce the risk of accidents by ensuring early detection and timely intervention.

1.1.2 Research Gap

Despite the progress, significant gaps remain in implementing these technologies, particularly in developing nations where affordability, accessibility and user awareness are critical barriers. This system relies on predefined thresholds and sensor inputs. It does not use machine learning or AI to predict potential leaks, user behavior patterns, or optimize responses based on historical data.Furthermore predictive analytics and automated response capabilities into a single affordable system remains a challenge.

1.1.3 Aims and Objctives

Motivated by these pressing issues, this research aims to design and develop a smart gas leakage detection, monitoring, and multistage prevention system using IoT. The goal is to provide a cost-effective, scalable, and reliable solution that addresses both safety and accessibility. By employing IoT's potential to integrate detection, communication, and prevention into a unified framework, this research seeks to contribute to household and industrial safety while promoting the sustainable use of LPG in an increasingly energy-dependent world. By designing and developing a smart, IoT-based gas leakage detection and prevention system, this project aims to bridge the gap between conventional safety measures and modern intelligent solutions. The ultimate goal is to save lives, prevent property damage, and promote a culture of proactive safety through accessible technology. The specific objectives of this study are as follows:

- To develop a system so that it automatically shut off gas flow from LPG cylinder when gas air mixture reached at preset level.
- To alerted the user about gas leakage and gas level of LPG cylinder, turn on exhaust fan and buzzer automatically.
- To analyse causes of leakages and prevention strategy for piped natural gas.
- To compare performance/reliability of IOT based proposed system with marketed/existing auto shut off device of LPG cylinder.

1.2 LPG Production Systems and properties of LPG

LPG (Liquefied Petroleum Gas) is produced through various systems and processes, depending on the source (natural gas processing or petroleum refining). LPG production is an integral part of natural gas processing and crude oil refining. In natural gas processing, heavier hydrocarbons, including propane and butane, are separated from the lighter methane molecules.

This separation occurs in cryogenic plants (low-temperature separation to recover LPG components) or during the extraction of Natural Gas Liquids (NGLs) [2].

Similarly, in crude oil refineries, LPG is extracted as a byproduct during fractional distillation and catalytic cracking processes. Both methods leverage the principles of phase equilibrium, manipulating pressure and temperature conditions to liquefy specific hydrocarbon fractions while retaining others in the gaseous state.

1.2.1 Types of LPG Production Systems

Liquefied Petroleum Gas (LPG) is not produced directly in its final form but is a by-product of other processes. There are two primary types of LPG production systems:

1.2.1.1 Natural Gas processing

About 63% is Recovered during the extraction of natural gas and oil from the earth. Commercial natural gas consists chiefly of methane, yet it likewise contains a blend of other gases and liquids, notably propane and butane. Natural gas processing differs from oil refining. To begin with, the water phase and the condensate are separated off and forwarded for refinement. During processing at the gas plant, the gas is stripped of acidic constituents like hydrogen sulfide (H2S) and they are subsequently recovered. Lastly, the liquids are extracted from the natural gas through a distillation process and then piped to market. Hence, prior to marketing the gas, some of its natural gas liquids such as LPG are first removed. LPG Production Process from natural gas processing:

1. Separation: Removal of water, CO_2, and H_2S (acid gases).
2. Fractionation: Separation of heavier hydrocarbons (propane and butane) from methane and ethane.
3. Compression & Cooling: The extracted gases are compressed and cooled into a liquid form.

1.2.1.2 Crude oil refining

Approximately 37% is produced during the refining of crude oil. LPGs are manufactured in somewhat different degrees of refinement which include atmospheric distillation, reforming and cracking. LPG contributes to 1-4 percent of crude oil processed depending on the nature of crude oil [3]. A lot of chemistry and physics go into the production of gasoline and the other products of crude oil that we use every day. It is mostly about heat. All the components present in crude oil boil at various temperatures and hence high heat is applied in order to separate them through a process known as fractional distillation. The process is illustrated in Fig. 1.1

Table 1. 1: Crude oil Composition by weight [3]

Carbon	Hydrogen	Nitrogen	Oxygen	sulfer	Metals
83-85%	10-14%	0.1-1.5%	0.05-1.5 %	0.05-6%	<0.1

1. Approximately 600 o C is used to heat the crude oil mixture.
2. The mixture of the super-heated oil becomes vapour, and then it is introduced into the fractionation column.
3. The vapor that climbs up cools at varying temperatures, which are dependent on the composition of the vapor. On cooling, it condenses to a liquid, a fraction and is captured in a tray.
4. Trays at the bottom of the column collect the fractions with high boiling point that condense rapidly. The fractions at low boiling point float to the top of the column then condense.

   At the top of the column there are a number of hydrocarbons with low boiling points between 20ºC and 70ºC these remain as gases [4].

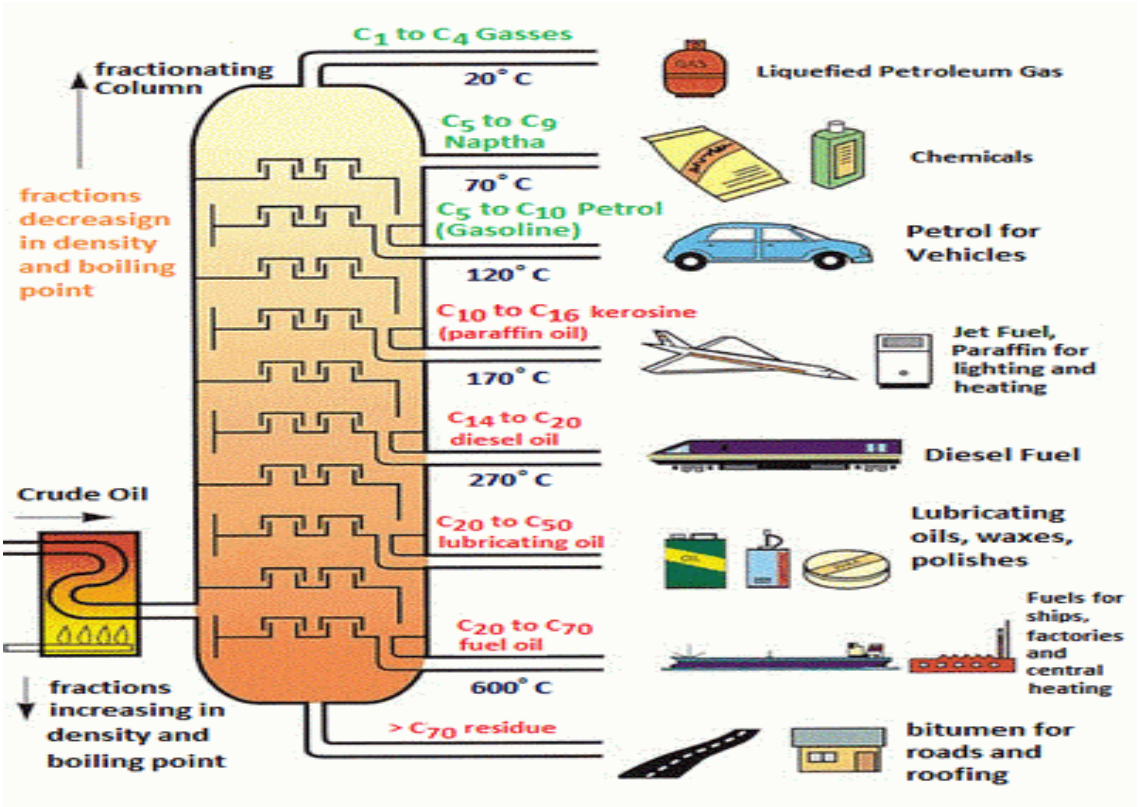


Fig.1.1: Fractional Distillation Column [4]

1.3 Route of LPG from production to the end-consumer

Fig.1.2 illustrates the supply chain of liquefied petroleum gas (LPG) from extraction to end use. It begins with oil and gas extraction, either onshore or offshore, followed by natural gas processing and crude oil refining. LPG is transported via tankers to refrigerated or pressurized storage terminals. From there, it is distributed to LPG bulk sub-depots and then either directly supplied to industrial, agricultural, and automotive users or sent to gas cylinder filling plants. Filled cylinders are delivered to retailers and ultimately used for household cooking. This flow highlights the complex logistics involved in ensuring safe and reliable LPG delivery to consumers.

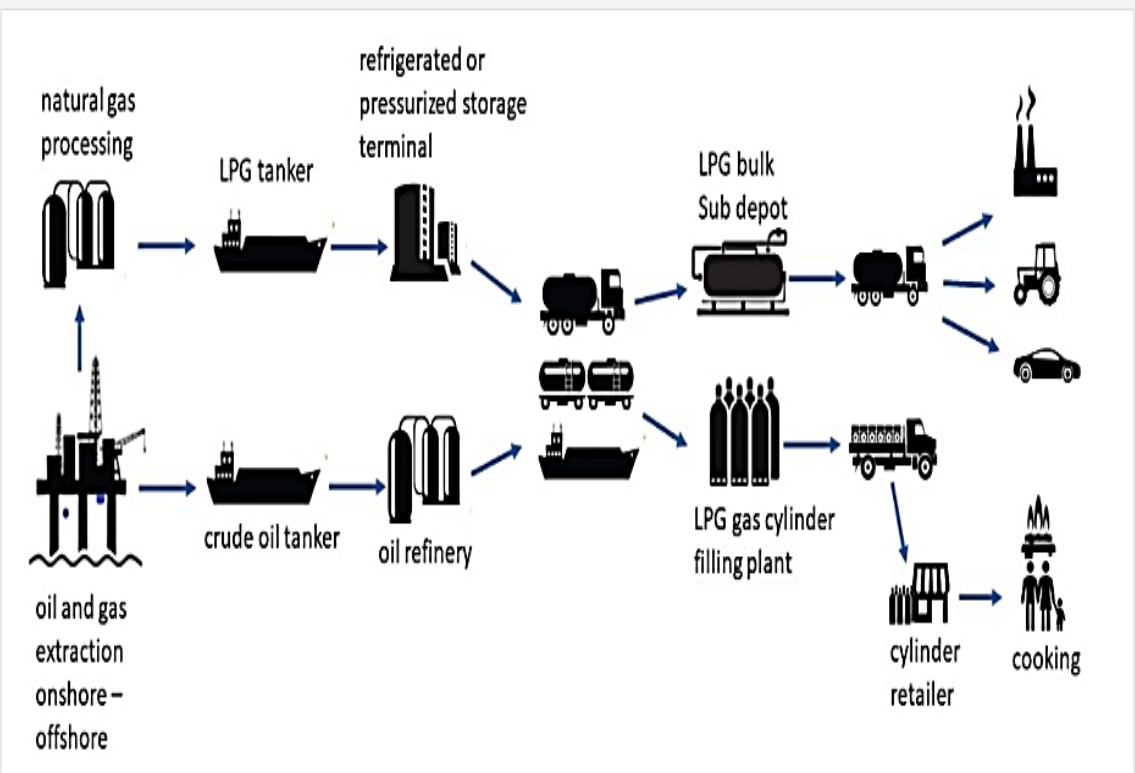


Fig.1.2: Route of LPG from production to the end-consumer [1]

1.4 Physical and chemical properties of LPG

Liquefied Petroleum Gas (LPG) is a versatile, clean-burning fuel commonly used in residential, commercial, and industrial settings. It is a mixture of hydrocarbon gases, mainly propane (C_3H_8) and butane (C_4H_{10}), and is stored in liquid form under moderate pressure. In Bangladesh, the typical composition of LPG (Liquefied Petroleum Gas) is primarily a mixture of Propane (C_3H_8) and Butane (C_4H_{10}). The exact ratio can vary slightly depending on the supplier and seasonal needs, but a common composition is:

- Butane: 60% to 70%; Propane: 40% to 30%.
- Higher Butane content is preferred in warmer climates like Bangladesh because butane is less volatile and safer to handle in higher temperatures.
- Propane is more commonly used in colder climates because it vaporizes at lower temperatures.

Table 1. 2: Properties of LPG [5, 6]

Properties	**Propane (C_3H_8)**	**Butane (C_4H_{10})**	**LPG (Propane 40% and Butane 60%)**
Physical State at 15° C and 1 atm	Gas	Gas	Gas
Molecular weight (gm/mole)	44.09	58.12	51-54
Boiling Point at 1 atm	-42.1°C	-0.5°C	-13
Reid vapor pressure at 15.6°C (bar)	12	3.6	5-7
Specific gravity of liquid at 15°C	0.51	0.575	0.555
Specific density of Vapor at 15C & 1 atm(kg/m3)	1.55	2.48	2.20 (Heavier than air)
Net calororific Value (vapor) at 15c (kcal/Nm3)	22600	29000	10896
Net calororific Value (Liquid) at 15c (kcal/Nm3)	10999	10845	10896
Explosive limit (vol% of vapor in air gas mixture)	2.4-9.3	1.8-8.8	2-10

The compressibility and flammability of LPG also make it unique. Its volume reduces significantly under pressure, with a gas-to-liquid ratio of approximately 250:1. This high compression ratio is economically advantageous, allowing efficient storage and transportation in pressurized cylinders [6]. However, its highly flammable nature necessitates stringent safety protocols. The thermodynamics of combustion govern its applications, with flammability occurring only within specific concentration limits in air known as the Lower Explosive Limit (LEL) and Upper Explosive Limit (UEL). For

propane, the LEL is 2.4%, while the UEL is 9.3%, and for butane, these values range from 1.9% to 8.6%.

1.5 Comparison of the physical properties of natural gas vs LPG

Natural gas (mainly methane) is a lighter fuel used in piped systems, while LPG (propane and butane) is stored as a liquid under pressure and used in portable applications. LPG has a higher energy content and density, but natural gas burns cleaner with lower carbon emissions. Both are colorless and odorless, with odorants added for safety. The compressibility and flammability of LPG also make it unique. Its volume reduces significantly under pressure, with a gas-to-liquid ratio of approximately 250:1. This high compression ratio is economically advantageous, allowing efficient storage and transportation in pressurized cylinders. However, its highly flammable nature necessitates stringent safety protocols. The thermodynamics of combustion govern its applications, with flammability occurring only within specific concentration limits in air known as the Lower Explosive Limit (LEL) and Upper Explosive Limit (UEL). For propane, the LEL is 2.4%, while the UEL is 9.6%, and for butane, these values range from 1.9% to 8.6%.

Table 1.3: Properties of Natural Gas Vs LPG [6]

Property	Natural Gas	LPG
Composition	Methane (CH_4) with small amount of ethane, propane and other gases. Mostly methane around 95%.	Mixture of propane and butane. Propane (40%) and Butane (60%).
State at standard condition	Gas	Gas (liquefied under pressure)
Density (kg/m³)	0.8 (at 15°C, 1 atm)	1.5–2.0 (at 15°C, 1 atm)
Energy Content	38 MJ/m³	93 MJ/m³
Boiling Point	-161.5°C (methane)	Propane: - 42 °C Butane: 0.1°C
Flammability Range	5-15% in air	2–10% in air
Storage	Stored as a gas in pipelines or tanks	Stored as a liquid under moderate pressure

Odor	Odorless (odorant added for detection)	Odorless (odorant added for detection)
Environmental impact	Produces CO_2 and water upon combustion. $CH_4+2O2 \rightarrow CO_2+2H_2O+Heat.$	Produces CO_2 and water upon combustion. $C_3H_8+5O_2 \rightarrow 3CO_2+4H_2O+heat.$
Transport	Pipelines or iquefied for transport.	Bottled in pressurized cylinders
Heating Value	900–1000 BTU/ft³	2500 BTU/ft³
Safety Concerns	Lighter than air, disperses upward	Heavier than air, pools in low areas

1.6 LEL and UEL of LPG and natural gas

The Lowest emission Level (LEL) characterizes the least concentration of a combustible in discuss that permits the blast. There can be a tall blast hazard indeed with xceptionally little gas concentrations, in truth the awesome portion of combustible gasses and vapors have the LEL Fig.1.3 underneath 5 % of volume. The upper explosive level (UEL) defines the most extreme concentration of fuel in discuss that will cause blast. Concentrations of the combustible over the UEL cannot create blast since of the deficiently concentration of the burner (ordinarily Oxygen) [61].

E.g. Methane (CH) L.E.L = 5 % = (50,000 ppm) and U.E.L=15%(150,000ppm)

20% of LEL = 1 % = (10,000 ppm)

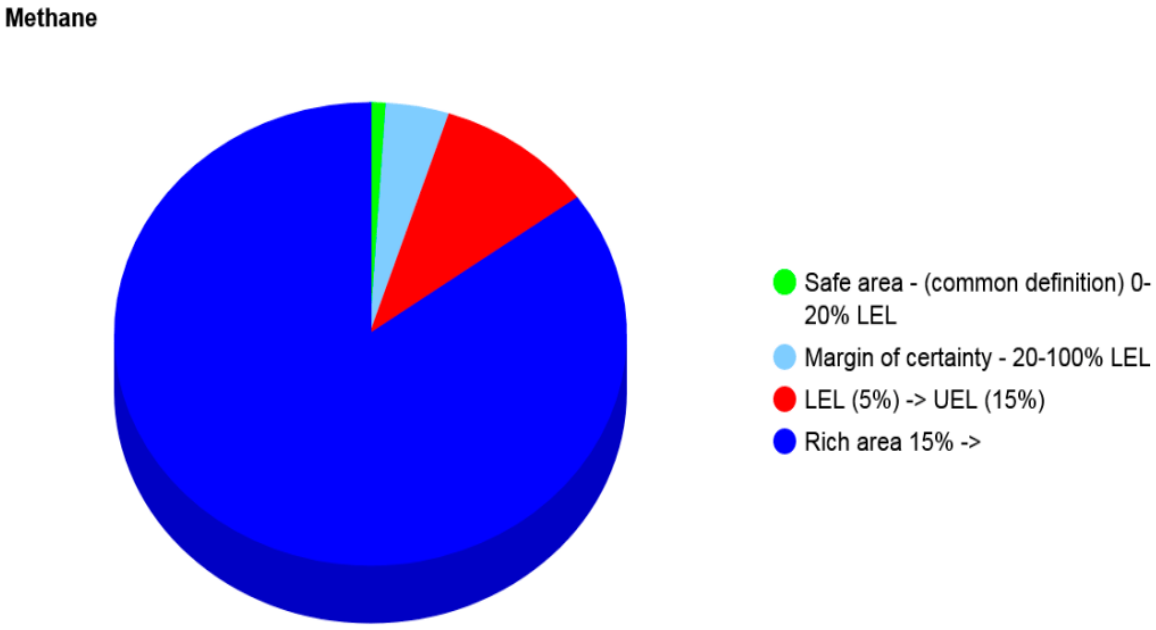


Fig.1.3: LEL and UEL of Methane [91]

Fig.1.4 illustrates the flammability range of propane gas based on its concentration in air:

- Green (Safe area: 0–20% LEL) – Represents the commonly accepted safe zone where propane concentration is too low to ignite.
- Cyan (20–100% LEL) – The margin of certainty, where concentration is increasing but not yet in the explosive range.
- Red (2.1%–9.5%) – The flammable or explosive range between the Lower Explosive Limit (LEL) and Upper Explosive Limit (UEL).
- Blue (Above 9.5%) – The rich area, where propane concentration is too high to sustain combustion due to insufficient oxygen.

Example

Propane(C_3H_8) L.E.L=2.1%(21000ppm)
U.E.L=9.5%(95000ppm)

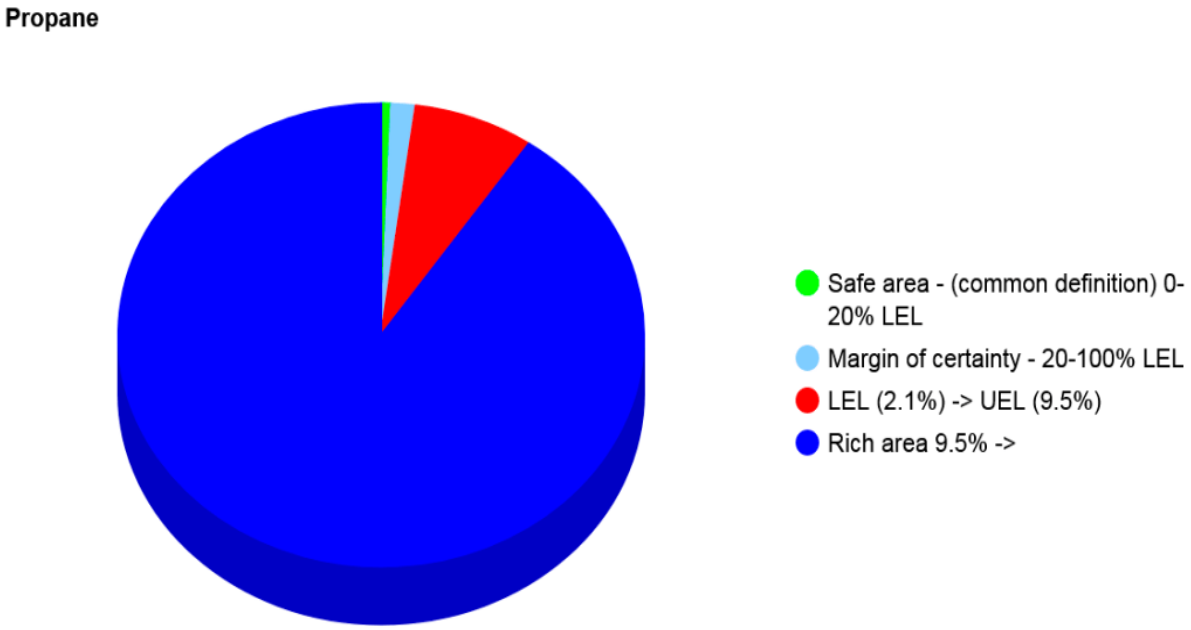


Fig.1.4: LEL and UEL of Propane [91]

Table 1.4: Gas concentration Unit [6]

Gas	LEL (%by volume)	UEL (%by volume)	LEL (PPM)	UEL (PPM)
LPG (Propane-Butane mix)	2.0%	10.0%	20,000 PPM	100,000 PPM
Natural Gas (Methane)	5.0%	15.0%	50,000 PPM	150,000 PPM

1.7 Applications of LPG:

The typical applications of LPG are now given below [2, 90]:

a. Domestic Sector: LPG has become a primary energy source for cooking and heating in households. Its clean combustion reduces indoor air pollution, which is particularly crucial in rural areas where traditional fuels like wood or coal are still used. Studies indicate that adopting LPG in households significantly lowers the incidence of respiratory illnesses caused by prolonged exposure to smoke.

b. Industrial Applications: In industrial settings, LPG is utilized as a fuel for kilns, furnaces, and boilers. Additionally, it serves as a raw material in the petrochemical

industry, where it is transformed into plastics, synthetic rubber, and other essential chemicals. Industries prefer LPG for its consistent combustion and easy storage.

c. Automotive Sector: LPG, in the form of autogas, is used in vehicles as a cleaner alternative to petrol and diesel. Countries like Italy, South Korea, and Turkey have adopted LPG extensively in their automotive sectors, citing its lower greenhouse gas emissions and cost-effectiveness.

d. Agricultural Use: In agriculture, LPG is employed for crop drying, weed control, and other purposes. Its portability makes it particularly useful in remote farming regions where access to conventional fuels is limited.

1.7.1 Recent Fire Incidents due to gas leakages

Despite its advantages, the improper handling and storage of LPG cylinders have led to numerous accidents. In 2022, a massive LPG explosion in Sylhet, Bangladesh, caused by a cylinder leak, resulted in the deaths of seven individuals and severe injuries to others. Investigations revealed that the absence of proper leak-detection systems and poor cylinder maintenance were primary contributors to the tragedy [12]. Here describe some recent fire incidents due to gas leakages.

- Death rises to 5 of gas cylinder explosion at Pallabi in capital dhaka on 14 november 2024. when lit a gas-lighter around 3am to light a coil to ward off mosquitoes, causing the fire. They all got burned in the process. Gas had accumulated in the room due to a leak from the house's gas line [69].
- Two people died and 07 Injured blast at a CNG filling station at rahmotpur in Mymensingh.The blast allegedly caused by a gas spill in a supply pipe happened when a private car was refueling at Azhar Filling Station and Intraco CNG Gas Pump on the Rohmotpur bypass around 3:00 pm Fig.1.5 [70].



Fig.1.5: CNG stations blast due to leakage of pipe line gas at Mymensingh city, 4 November, 2024 [70]

- Four passed away on impact at CNG filling station in Lakshmipur (14 october, 2024) 14 other individuals were harmed within the blast. The impact separated a few of their hands and feet from their bodies four individuals have passed on after an blast at a CNG filling station whereas a transport was refueling in Lakshmipur. The occurrence happened on Sunday night at the Ward No. 11 Green Leaf filling station within the Lakshmipur Region. The transport named 'Maisha Ikra Classic' was working beneath the pennant of 'Classic Meghna', said Abdul Manaf, chief of the Sadar Police Station. Three individuals were murdered on the spot when the blast happened. A fourth casualty kicked the bucket afterward on [71].

- One person lost his life in a gas-cylinder explosion at Dhamrai CNG station on 18 October 2024. Faruk Hossain, 50, the deceased identified as, resided in Dhaira town, Dhamrai and was employed as a driver for a rental service. The incident occurred nearly at 11:30 am at NN CNG and Refueling Station along the Dhaka–Aricha Interstate in Dhamrai. According to witnesses, Faruk Hossain was driving the vehicle while the station personnel attached the gas line to the cylinder. Faruk himself remained positioned behind the vehicle. In an instant, the gas cylinder went off, causing him to die immediately. The blast likewise left a car parked behind the microbus damaged Fig.1.6 [72].



Fig.1.6**:** Gas cylinder explosion at Dhamrai CNG station on 18 October 2024 [72]

- In the upazila of Kaliakoir in Gazipur, the gas cylinder explosion reaches 14. At least 35 individuals (women and children) were burned following an explosion of a gas cylinder that occurred in Kaliakoir on 13 March, 2024. The mother of a victim mourns in the street in front of a building called the Sheikh Hasina National Institute of Burn and Plastic Surgery, Dhaka, Fig.1.7 [73].



Fig.1.7: Gazipur LPG cylinder blast on 13 march, 2024[73]

- The Fire service and civil defence division is examining a suspected gas cylinder blast as the likely cause of the annihilating fire at the Green Cozy House on Dhaka's Bailey Street. At slightest 44 individuals kicked the bucket within the blast on Thursday, whereas another 22 individuals were hospitalized in basic condition, enduring burns to their respiratory tracts, Fig.1.8 [74].



Fig.1.8: Gas cylinder explosion of the devastating fire at the Green Cozy Cottage on Dhaka's Bailey Road on 29th Feb 2024[74]

In November 2018, 03 individuals of a family were slaughtered and 05 others harmed in a Melted Petroleum Gas (LPG) barrel blast at Aramnagar of Joypurhat region, Fig.1.9 [75].



Fig.1. 9: Accident due to LPG leakage in 2018, Joypurhat [75]

- Another occasion happens with those utilizing gas cylinder. They did not figure it out anything [suspicious] and when they light a matchstick to light the stove, fire breaks into the whole room. It may be their carelessness that driven to the collection of gas causing the fire. ”As gas fire scenes have gotten to be visit, individuals are getting pushed [76]. Niloy a 3-year-old boy, is being transferred to a post-operative

care room after undergoing treatment of his wounds on the 5 th floor of the Sheikh Hasina National Institute of Burn and Plastic Surgery, Fig.1.10.



Fig.1.10**:** Fire incident due to cylinder gas leakage [76]

From above gas leakage incidents, whether from pipeline infrastructure or domestic LPG cylinders, pose serious threats to life, property, and the environment. Over the years, numerous fire explosions, structural damages, and tragic fatalities have resulted from undetected gas leaks. Traditional gas safety mechanisms often rely on manual detection, which can be slow and unreliable, especially during off-hours or in unattended areas. In contrast, our proposed smart gas leakage detection and prevention system employs real-time monitoring using advanced sensors, IoT technology and automated safety protocols. These systems can detect even minute concentrations of leaking gas instantly alert users via alarms and mobile notifications and in some cases automatically shut off the gas supply to prevent escalation. This not only minimizes the risk of fire or explosion but also provides critical early warnings that can save lives and reduce property loss. Moreover, this systems can be integrated into smart home or industrial automation frameworks, ensuring seamless, round-the-clock protection. In a world increasingly reliant on gas for energy, investing in smart detection and prevention technology is not just beneficial, it is essential for public safety and resilience also.

1.8 Statistics of Fire Incidents from line Gas and LPG Cylinder

According to data from the Bangladesh Fire Service and Civil Defense (BFSCD), there were 852 incidents in 2017, resulting in 1,295 injuries and 81 fatalities. In 2018, 662 accidents resulted in 15 fatalities and 249 injuries. According to the Division of Explosives' annual report, 193 Cylinder explosions occurred in Bangladesh during the 2016–17 fiscal year. [77]. Gas-related fire occurrences cause passings and wounds very as

often as possible. A few of the casualties survive but they still endure after returning from the clinic taking after therapeutic treatment. As Bangladesh's socio-economic condition has changed quickly, most of the urban populace live in little flats and are compelled to utilize gas stoves rather than earthen stoves that utilize wood as fuel. Not all of the urban houses have gas pipelines so the request for gas barrels has expanded. The clients, be that as it may, feel on edge due to the uptick within the number of gas fire incidents. At least 20 percent of the whole populace within the nation of 20 million individuals utilize LPG whereas 25 percent utilize the gas provided through pipelines, as per the Division of Explosives. Others utilize distinctive sorts of stoves.

Concurring to BFSCD information, in 2023 alone, there were 230 mishaps ascribed to cylinder blasts, coming about within the misfortune of 20 lives. On September 4, 2020, 34 individuals kicked the bucket in such an blast in a mosque in Narayanganj. On January 24, five Rohingya children kicked the bucket in a gas fire discharged from a gas barrel in Bhasan char, hatia, Noakhali. Prior on December 11, one individual kicked the bucket in a gas barrel blast in a material process in tongi, Gazipur. Hence, due to need of mindfulness and carelessness, mishaps caused by LPG Cylinder are frequently causing casualties [78]. Furthermore, ten people were burnt in fire mischances by gas cylinder leak in Ashulia (13 Aug, 2023, Everyday star) [79], Four family individuals burnt in gas blast in Narayanganj (17 Dec,2023, dhaka tribune) [80] and 07 young people harmed in Savar gas spill blast (18 Nov, 2023, dhaka tribune) [81].

The occurrences result in an hoisted fetched, counting misfortune of life, harm to property, commerce and supply chain disturbance, and misfortune of basic products and these misfortunes will be expanded with expanding of fire occurrence dangers. According to annual report of Bangladesh Fire Service and Civil Defense (BFSCD) and Newspaper report which is described in table 1.5- [75, 85].

1.8.1 Annual report (2017-2023) of Accident According to Bangladesh Fire Service and Civil Defense

Between 2017 and 2023, Bangladesh experienced a significant number of accidents related to gas lines and LPG cylinders. The highest number of accidents occurred in 2020 (957 incidents), while the most injuries were reported in 2017 (1,295 people). That same year also recorded the highest number of deaths, with 81 fatalities. Although the number of accidents slightly decreased in some years, the financial loss peaked in 2023, reaching

Tk 332.5 million, indicating more severe damages despite fewer casualties compared to 2017. Overall, the data shows a fluctuating trend in accident frequency and severity, highlighting ongoing safety challenges in the handling and use of gas in Bangladesh.

Table 1. 5: Annual report of Bangladesh Fire Service and Civil Defense:

Year	No of accidents (From line gas and LPG cylinder)	Injured (Number)	Died (Number)	Financial Loss/damaged (Tk million)
2017	852	1295	81	
2018	662	249	15	
2019	818	69	25	121.5
2020	957	107	10	38.8
2021	894	163	10	39
2022	767	51	8	51.8
2023	904	90	25	332.5

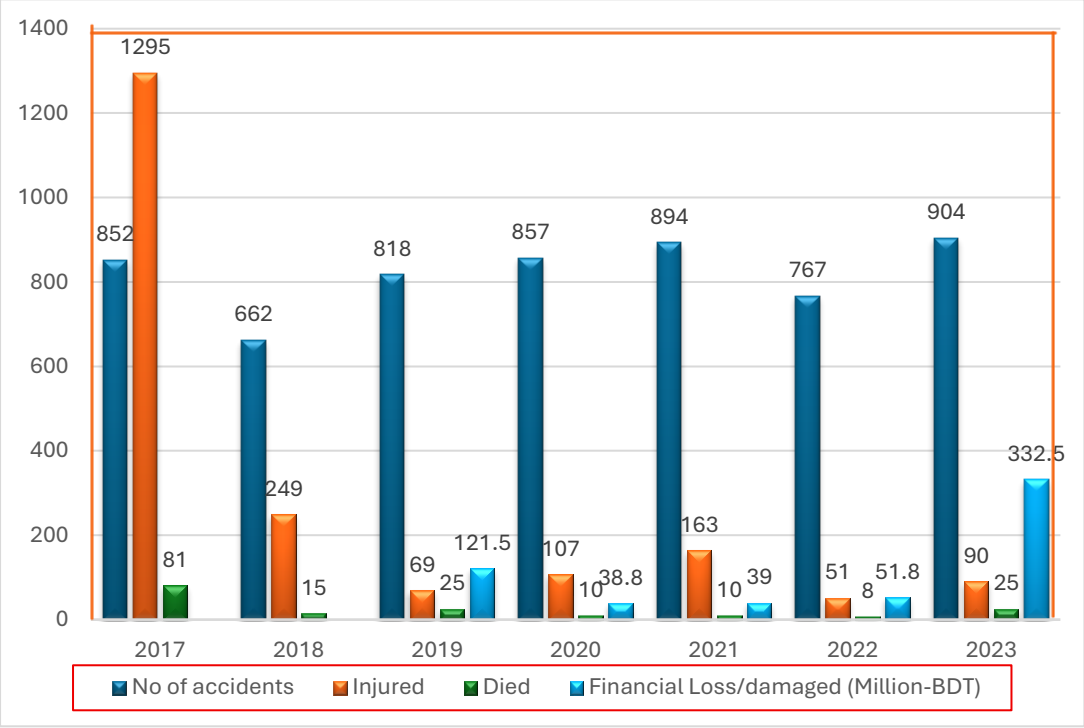


Fig.1.11: Statistics of fire incident from line gas and LPG cylinder (2017-2023) [85]

From Fig. 1.11 shows that, there were 94 incidents of LPG cylinder fires in 2022, which increased to 210 in 2023. That is, with the increase in the use of cylinders, the incidence of fire is also increasing every year. According to the data of the burn unit of Dhaka Medical College (DMH) Hospital, 66 people have been burnt by gas fire since June last year. More than 3,000 fire mischances happen in Dhaka city each year, that's cruel there are around 10 fire mischances within the capital each day from gas blast [82]. In another incident in India, an LPG explosion in Maharashtra devastated a residential area, killing multiple residents. This was attributed to a faulty regulator and inadequate ventilation in the storage area. Such incidents underline the critical importance of adopting advanced detection and prevention technologies to enhance LPG safety [83]. The causes of fire incident from LPG cylinder and pipe line gas [92, 97] are described in the below Table 1.6.

Table 1. 6: Causes of leakage form LPG Cylinder and pipeline gas

Main Causes of leakage from LPG cylinder:	Causes of Leakages of Piped Natural Gas:
• Missing/Damaged O-Ring in the cylinder • Damaged hose pipe/Tube • Faulty Regulator/ Faulty connection system from cylinder to stove • Loose connection of fittings (clamp, hose pipe) • Low quality accessories, • Negligence to switches off the regulator after cooking	• Connection and Fitting Errors • Defective Appliances • Use of Low-Quality Material • Extreme Pressure Variations • Schedule Regular Appliance Maintenance • Gas line corrosion

Another causes are when the Gas cylinder are not transported appropriately and there's too a need of security in putting away and illicit refill production line/ filling gas into the little barrels from the big ones. This is often an illicit and hazardous. The steel within the barrels gets to be pricier when sold as rejected press. “The wholesaler finds it beneficial to offer the barrel to scrap metal dealers for Tk 2,000 rather than the company for Tk 500.” In some cases, mischances happen when the cylinder are scrapped without degasification.”

The larger part of family episodes are ascribed to gas spillage, basically stemming from surrenders within the barrel interfacing pipe, stove elastic, or controller.
This spillage may a mass inside the limits of a closed house, making a profoundly unstable environment. Ultimately, an electric start or any source of start can trigger a disastrous blast beneath these circumstances.
To Reduce incident due to gas leakages following security information must be needed to know the LPG user [84]:

1. Leakage Check some time recently association and detachment of LPG cylinder
2. Security information amid interfacing full barrel of LPG.
3. Security information approximately lighting gas stove.
4. Information around deplete fan/ventilation.
5. Spill location and spill risk.
6. Information around gas locator hardware.
7. Knowledge about fire assurance gear.
8. Information almost elastic tube and controller change.
9. Information about expiry date of LPG cylinder.

1.8.2 Another Method to Detect Leaked In Pipeline Gas By Adding Odorant:

In pipe line gas routinely adding/injecting an odorant (mercaptan fluid, contain sulfur compounds) into gas stream (272 gm/MMSCF) to form the gas scent so that fectively can distinguish gas spillage, since common gas is odorless. Gas blasts in homes happen in created nations as well. But they have diminished the number of mishaps through open mindfulness, standard review and repairing gas associations as well as having standard fire drills. Some people have absolutely wrong idea about gas discovery framework. Nearly 93% (162 of 175) LPG cylinder gas clients of private zone concurred that gas spillage is unsafe and fire danger may happen from the spillage. 85% inn and eatery shoppers too know that gas spillage is destructive and mischance may happen from this spillage.

1.9 The Role of IoT in Enhancing LPG Safety

This is the net of physical things, automobiles, appliances, and other objects, which have sensors, software, and connectivity to allow them to collect and exchange information; this is referred to as the Internet of Things (IoT). The Internet of Things (IoT) has revolutionized many sectors, including safety and monitoring systems for industrial and

domestic applications. An IoT-based gas leakage detection and prevention system plays a critical role in ensuring safety, optimizing resource usage, and enhancing emergency response. Here are some key roles and benefits of such systems [88]:

Real-Time Monitoring

• Continuous Surveillance: IoT-enabled gas sensors constantly monitor for the presence of hazardous gases like methane, propane, or carbon monoxide, providing real-time data to users and systems.

• Instant Alerts: Once a gas leak is detected, the system can instantly alert users (via smartphones or other devices) and automated systems, enabling immediate action.

Data Analytics

• Historical Data Collection: These systems can store data over time to analyze trends and usage patterns, helping in predicting potential hazards or maintenance needs.

• Predictive Maintenance: By analyzing data from sensors, maintenance can be scheduled proactively, reducing the likelihood of leaks due to equipment failure.

Automated Safety Responses

• Shut-off Mechanisms: In the event of a detected leak, IoT systems can trigger automated shut-off valves to stop gas flow, minimizing the risk of fire or explosion.

• Ventilation Control: Systems can activate ventilation mechanisms to disperse any leaking gas, further enhancing safety.

Integration with Other Systems

• Smart Home Integration: In residential settings, gas detection systems can be integrated with smart home systems to ensure coordinated responses, like turning off appliances and activating alarms.

• Emergency Services Notification: The system can be programmed to automatically notify emergency services when a leak is detected, improving response times.

Remote Monitoring and Control

• Accessible from Anywhere: Users can monitor gas levels and system status remotely via smartphones or computers, providing peace of mind, especially in industrial settings or isolated areas.

• Control Capabilities: Users can remotely engage shut-off valves or ventilation systems, enhancing control during emergencies.

Regulatory Compliance

• Adherence to Safety Standards: Many IoT gas detection systems are designed to comply with local and international safety regulations, helping companies meet legal requirements.

Cost-Effectiveness

• Reduced Downtime: Early detection and prevention of leaks minimize operational downtime, safeguarding both assets and human lives.

• Insurance Benefits: Installing a gas leakage detection system may lead to lower insurance premiums due to reduced risk.

Environmental Protection

• Minimizing Gas Emissions: By ensuring prompt detection and response to gas leaks, IoT systems help reduce environmental impact due to harmful gas emissions.

User Education and Training

• Alerts and Training Modules: Some systems can offer educational resources and alerts to train users on safe practices, potential hazard signs, and emergency measures.

Scalability and Flexibility

• Customizable Applications: IoT solutions can be tailored to fit various environments, from small homes to large industrial plants, making them universally applicable.

The Internet of Things (IoT) offers a revolutionary approach to mitigating LPG-related risks. IoT-enabled systems integrate sensors, microcontrollers, and real-time communication tools to detect gas leaks, monitor cylinder pressure, and automate safety responses. Sensors such as MQ-2 and MQ-6 are widely used to measure LPG concentrations, while microcontrollers like Arduino and NodeMCU provide the computational backbone for these systems [9].

Advanced IoT-based setups not only detect leaks but also trigger preventive mechanisms such as shutting off gas supply valves, activating exhaust fans, and sending mobile alerts. These systems can be integrated into smart home environments or industrial facilities, providing scalable and reliable solutions to LPG safety challenges [10].

1.10 Future of IoT

IoT is expected to grow rapidly with advancements in technologies like 5G, edge computing, and artificial intelligence (AI). During the past ten years, Internet of Things (IoT) platforms have expanded to become a global giant, engulfing every aspect of our daily lives and boosting human life with their uncontrolled smart services. Without

actively searching for knowledge and data patterns, machine learning namely ML enables IoT to glean hidden perceptions from the wealth of vital data and become genuinely pervasive. IoT's main objective is to help us understand what is going on in our background and enable automated decision-making using clever techniques that resemble human decision-making. These innovations will enable faster, more reliable communication, real-time data processing, and smarter decision-making.

1.11 Outline of the Thesis

This experimental work thesis is organized into five chapters. A brief summary of each chapter is presented below:

Chapter 1: Introduction
This chapter presents the background and motivation of the study, clearly stating the problem, research gap, and the aims and objectives. It provides an overview of the LPG production process and the properties of LPG. Recent fire incidents caused by gas leakage are discussed, along with the causes of leakage from LPG cylinders and pipeline gas systems. The chapter also highlights the role of IoT in enhancing LPG safety.

Chapter 2: Literature Review
This chapter reviews previous research related to LPG leakage detection, monitoring, and prevention systems. It provides a detailed evaluation of recent studies, examining their methodologies, findings, limitations and identifies the areas that require further investigation and development.

Chapter 3: Methodology
The first section of this chapter describes the hardware design and components of the proposed system, followed by a detailed discussion of the software design and implementation process. The system workflow is presented, along with clarification of the objectives of this study. The chapter also includes the results of electrical simulations using Proteus, details of the instruments used, and brief descriptions of the experimental equipment.

Chapter 4: Result and Discussion
This chapter provides an in-depth analysis of the LPG detection system. It begins with a discussion of the results obtained from the MQ-6 sensor, followed by an explanation of the multistage protection system. The integration of the entire system is then presented,

along with a financial breakdown, demonstrating that the proposed solution is both cost-effective and efficient.

Chapter 5: Conclusion and recommendations

This chapter summarizes the key findings of the study, highlighting its main contributions and providing final remarks on the effectiveness of the developed system. It reflects on the broader implications of the research, identifies potential improvements, and suggests directions for future work. Additionally, it offers safety recommendations for the use of LPG cylinders to reduce the risks of leaks, explosions and fires.

Chapter 02

Literature Review

2.1 Introduction

The growing reliance on Liquefied Petroleum Gas (LPG) as a primary energy source in residential and industrial purposes has heightened the need for advanced safety systems to prevent gas-related accidents. Recent advancements in the Internet of Things (IoT) have enabled the development of smart gas leakage detection, monitoring, and prevention systems. These systems utilize technologies like Arduino, Raspberry Pi, and various microcontrollers to detect leaks, provide real-time alerts, and implement preventive measures such as valve closures or ventilation activation. The literature surrounding this field highlights numerous innovative solutions that address gas safety concerns while also revealing gaps, particularly in automation, scalability, and multistage prevention capabilities. This chapter provides a detailed review of recent studies, evaluating their methodologies, findings, and limitations to identify areas requiring further exploration and development.

2.2 Previous related studies

Chakradhar [11] proposed a smart LPG cylinder leakage detection system that integrates an MQ6 gas sensor with an Arduino microcontroller and an ESP8266 IoT module. The system detects gas leaks and provides real-time notifications via a web browser. Alerts are conveyed through a buzzer and LED indicator, ensuring prompt user awareness. This low-cost, efficient system is well-suited for domestic and small-scale industrial applications. The primary innovation lies in its seamless integration of IoT for remote monitoring and notification. However, a significant limitation of this study is the absence of preventive mechanisms beyond alert generation. For example, the system does not feature automated interventions such as gas valve closure or ventilation activation, which are critical for preventing accidents. Additionally, its reliance on internet connectivity could limit its effectiveness in areas with unstable networks.

While the study focuses on affordability and usability, it highlights a need for future research to incorporate multistage preventive mechanisms and enhance reliability. The system's design is also limited to detecting LPG, potentially excluding other hazardous gases. Overall, this work contributes to advancing IoT-based gas safety solutions but

leaves room for further development in automation and scalability. Rekha [12] developed an IoT-enabled gas leakage detection system using Arduino Nano and MQ-2 gas sensors. The system features a GSM module for real-time notifications, sending alerts via SMS to users. A buzzer and LED indicator provide local warnings for immediate response. The primary gases detected include LPG and carbon monoxide, which are common in both residential and industrial environments. The study emphasizes affordability and accessibility, making it a viable solution for small-scale settings. However, the system's capabilities are limited to detection and alerting, without incorporating automated safety mechanisms such as valve closures or ventilation activation. Additionally, the system's reliance on SMS-based alerts could face delays in regions with poor cellular connectivity. While the authors successfully demonstrate the system's effectiveness in detecting hazardous gases, their methodology does not address scalability for larger or more complex environments. Another limitation is the absence of cloud integration, which could provide data logging and advanced analytics for gas concentration trends. Future research could focus on integrating IoT platforms for enhanced monitoring and multistage prevention measures. This study provides a strong foundation for gas safety solutions but requires further development to address its gaps and expand its application scope.

Sharma [13] designed a cloud-based IoT gas leakage detection system, integrating Arduino Uno, an MQ-2 gas sensor, GPS, and a smoke detector. The system identifies gas leaks, sends alerts via SMS and email, and provides real-time location tracking using GPS. Additionally, the smoke detector enhances safety by identifying potential fire hazards, and the system's data is visualized through a user-friendly cloud interface.

While the system excels in real-time alerting and location precision, it lacks automated interventions to mitigate risks, such as shutting off gas valves or activating exhaust systems. The research primarily focuses on residential and commercial settings but does not address industrial-scale applications where robust automation is crucial. Another limitation is its reliance on internet connectivity for cloud functions, which could hinder performance in areas with poor network coverage. Despite these challenges, the system offers an affordable and scalable solution for gas leakage monitoring. Future iterations could incorporate local control features and multistage prevention to enhance its applicability in diverse environments. This study contributes to the growing body of IoT-enabled safety systems and demonstrates the potential of integrating GPS for precise incident localization.

Naveen [14] proposed a gas leakage detection system built on the ATMEGA328 microcontroller. The system features an MQ6 sensor, a GSM module for SMS notifications, and a servo motor for shutting off gas valves. It includes an LED, buzzer, and exhaust fan for immediate responses to leaks. The integration of a servo motor for valve closure represents a key innovation, addressing the need for multistage prevention. The system successfully prevents potential accidents by providing real-time alerts and automated physical interventions. However, the study focuses on small-scale applications and lacks scalability for industrial environments. Additionally, the system does not incorporate IoT cloud platforms, which could provide advanced features like remote monitoring and analytics. While effective, the system's dependency on GSM networks may face challenges in areas with poor cellular connectivity. The study demonstrates significant progress in gas safety technologies but leaves room for integrating IoT for enhanced functionality and scalability.

Sandhra and Manjunatha [15] developed a safety system for petrol pumps to detect benzene leaks using MQ135 sensors, Arduino Uno, and GSM modules. The system focuses on monitoring benzene a highly carcinogenic gas—and provides real-time alerts via SMS. By addressing occupational hazards in petrol stations, the study highlights the importance of continuous air quality monitoring for hazardous chemicals.
The system’s simplicity and affordability make it accessible for implementation at fuel stations. However, its scope is limited to detection and alerting without any preventive measures like automatic shutdown of dispensing units or enhanced ventilation. Moreover, while the study focuses on benzene, it does not explore how similar methods could be adapted for detecting other gases, such as LPG or methane, that pose significant risks. The system's reliance on GSM also limits its effectiveness in areas with poor network connectivity. Future work could extend the methodology to incorporate IoT cloud platforms for enhanced data logging, real-time analysis, and automated safety measures. Overall, this research serves as a foundational study for deploying IoT-based safety systems in specialized environments but lacks multistage safety features to ensure comprehensive risk mitigation. Additionally, Anika [16] introduced a comprehensive gas leakage detection system integrated with automated ventilation and fire-extinguishing mechanisms. The system uses Arduino Uno, MQ2 sensors, and IR fire sensors to detect leaks and fires. It activates exhaust fans to reduce gas concentration and utilizes water

spray systems to extinguish flames. Alerts are sent to users via the Blynk application. This multistage system provides a holistic approach to mitigating risks associated with gas leaks. The inclusion of fire-detection capabilities and automated responses represents a significant advancement in safety technologies. However, the study's testing scenarios are limited to controlled environments, leaving questions about its performance in real-world applications. Additionally, its dependency on app notifications without supplementary local warnings (e.g., sirens or flashing lights) could reduce its reliability in areas with limited connectivity. Future research could expand the system's capabilities to include integration with IoT platforms for cloud monitoring and analytics. Despite these limitations, the study demonstrates the potential of IoT-enabled multistage prevention systems to significantly improve gas safety.

Michael [17] designed a multifunctional smart home automation system integrating gas leakage detection, intrusion detection, and lighting control. Using Raspberry Pi, Arduino Uno, MQ2 sensors, and the Telegram app for notifications, the system offers a diverse range of features. For gas detection, MQ2 sensors identify the presence of LPG, and notifications are sent to the user via the Telegram app. While the inclusion of multiple features enhances the system's versatility, the gas detection functionality lacks robust preventive measures like valve control or ventilation activation. The system's primary limitation is its broad scope, which may dilute its focus on specific safety features like gas leak prevention. Future work could refine the gas detection module by incorporating IoT-based automation for real-time mitigation of leaks. Despite its limitations, the study highlights the potential of integrating gas detection into broader home automation systems, demonstrating a scalable approach for smart home technologies.Praveenchandar [18] developed a toxic gas monitoring system incorporating IoT and deep learning for predictive analytics. Using Arduino Uno and sensors like MQ3 and PID detectors, the system monitors gases such as LPG, CO, and SO_2 transmitting data to a cloud platform for analysis. A hybrid model combining Hidden Markov Models (HMM) and Artificial Neural Networks (ANN) improves detection accuracy and reduces false positives. While the system demonstrates advanced analytics and predictive capabilities, its focus remains on industrial applications, leaving household and small-scale implementations unexplored. Moreover, the study does not include automated preventive measures, such as gas valve control or ventilation activation, which are critical in emergency scenarios. Future iterations could focus on real-time control mechanisms to address these gaps. This

study contributes to the advancement of IoT in industrial safety by integrating data science techniques, but its practical applicability in diverse settings remains limited. Uzair [19] developed a comprehensive IoT-enabled building management system that integrates gas leak detection alongside energy monitoring and control. Using Raspberry Pi, Arduino Mega, and NodeMCU, the system monitors environmental parameters and provides real-time alerts for anomalies, including gas leaks. The architecture uses MQTT protocols for efficient communication and supports local data storage, reducing dependence on cloud services. While suitable for large-scale applications, the system's high implementation costs and complexity limit its adoption in smaller setups. Future work could explore cost-optimization strategies to expand its applicability. Shelke [20] designed a real-time gas leakage detection system using MQ6 sensors and Arduino microcontrollers. Alerts are sent via IoT platforms, enabling remote monitoring. The system is effective in identifying methane, propane, and butane gases. However, its scope is limited to detection, lacking preventive features like valve control or ventilation activation. Future work could address these limitations to improve applicability in both household and industrial settings.

Many researchers are also working in the field of home automation and safety system leveraging IoT technology. Chattopadhyay [21] proposed an IoT-based smart home automation system that includes gas leakage detection as a safety feature. Using Raspberry Pi and DHT22 sensors, the system monitors gas concentrations, temperature, and humidity. The integration with Google Assistant enables voice-based commands and real-time alerts via Firebase notifications. The system demonstrates an innovative approach by combining gas detection with general home automation functionalities. However, the study focuses primarily on detection and lacks preventive mechanisms such as ventilation activation or gas valve control. Its reliance on internet connectivity may also limit its applicability in regions with poor network infrastructure. While the system effectively integrates multiple functionalities, it prioritizes convenience over comprehensive safety measures. Future research could refine the gas safety module, incorporating automated preventive actions and enhancing scalability for diverse applications. Balaji [22] introduced a smart home security system integrating gas detection as a secondary feature. Using Raspberry Pi3 and PIR sensors, the system monitors movements and gas concentrations, sending alerts via email and SMS. While primarily focused on security, the gas detection feature provides an additional layer of safety. The system lacks multistage prevention measures such as automated gas shutdown or ventilation, which

limits its effectiveness in addressing gas hazards comprehensively. Moreover, the inclusion of multiple features may dilute its focus on gas safety. Future iterations could prioritize gas detection and integrate IoT platforms for enhanced monitoring and automation. Manhas [23] designed a gas leakage detection system using Node MCU and MQ sensors, offering real-time monitoring and alerts via an Android-based app. The system continuously tracks gas concentrations, providing early warnings to prevent accidents. However, it focuses on detection alone and lacks preventive mechanisms such as valve automation or ventilation control. Its simplicity and affordability make it suitable for residential use but limit its scalability for industrial applications. Future enhancement. Islam [24] developed an IoT-enabled system for detecting gas leaks, electrical faults, and fires in indoor environments. Using Arduino and sensors, the system automatically disconnects power supplies and sends alerts via ThingSpeak. The integration of automated preventive measures and cloud-based monitoring ensures comprehensive safety. However, the system's scalability and real-world performance require further evaluation. Future work could focus on optimizing the system for diverse environmental conditions. Suhartono and Suhadi [25] presented a gas pressure monitoring system using Arduino Mega, MQ6 sensors, and GSM SIM900 modules. The system sends SMS alerts upon detecting abnormal gas pressures, ensuring timely user intervention. The experimental methodology demonstrates effectiveness in small-scale scenarios but lacks IoT integration for real-time analytics. Future enhancements could include cloud connectivity and automated preventive mechanisms for enhanced safety. Meenakshi et al. [26, 37] proposed the leakage detection and real time gas monitoring system. In this system, the gas leakage is detected and controlled by means of exhaust fan. The level of LPG in cylinder is also continuously monitored. But there also lacks of IoT integration for real-time monitoring and not intregated automated preventive mechanisms for enhanced safety.

Derryn et *al.* [27,42,51,62] The leak in the gas cylinder domestic, as well as that of industrial areas, is detected by using a system designed that has an MQ-5 sensor that detects LPG, natural gas, etc. The MQ-5 sensor is used where they sense the presence of LPG in the air and coordinate with the microcontroller which transmits a message to the user informing him that there is a gas leakage. This solenoid valve installed in the set-up locks the knobs hindering further escape of LPG. Sarika et *al.* [28,39,40] proposed the system where LPG cylinder is subjected to surveillance and automatic reservation of the cylinder and gas Leakage prevention. Introducing Digital interface load cell, using

Arduino-UNO. And gauge the weight of LPG cylinder when weight of the cylinder falls below the limit value it gives a signal to the gas agency to do booking.
Shivalingesh [29] made one arrangement such that the amount of gas in the air is detected and when it becomes high than the safety level, he delivers a SMS to the consumer through GSM modem and the audio-visual alarm, which consists of LED, Buzzer alerts to the user, at home in the abnormal condition and to take measures and the message is also displayed on LCD screen. However, it does not have IoT implementation of the real-time monitoring and preventing safeguards automation of close cylinder knob.

Krishna [30] has suggested the approach that makes the automatic control act when a detecting gas is discovered. This would turn off the regulator valve (motor) and this totally prevents the flow of gas leakage. When the leakage occurs, it alerts the user using internet in his device and a feedback is forwarded to the microcontroller to close the valve. In this process, the weight of the gas cylinder is monitored by a sensor (load cell) and in case it drops below the critical measure, the sensor perceives this situation and sends an alert message over the internet to gas agency to book a LPG. But not integrated how to control emergency situation. Priya [31] proposed a system, when a leakage occurs gas sensor detects leakage and sends signal to the arduino which turns off the gas valve. Gas leakage monitored by PIR sensor and sends signal, After receiving proper signals, the arduino decides whether to off the valve or keep it turned on. LPG to be detected is the Jebamalar [32] which uses MQ-6 gas sensor. The output of the gas sensor is fed into dual operational amplifier and compared with the threshold value of gas density which is set by preset potentiometers and amplified. When sensed voltage increases above the preset threshold voltage, then the driver circuit of LED and Buzzer is activated by firing the output of operational amplifier. Consequently, LED will become bright and the alarm sound through the buzzer will begin to ring.

According to Wickramasinghe [33], the device had two modules which are, (1) the gas detector and the centralized alarm unit. LP gas sensor senses after an interval of 5 minutes and in case the ppm level exceeds 1800, the sensor module transmits address bit to alarm unit which causes the buzzer to turn on. In case the level of risks is higher than the alarm rings. Back up battery unit can survive many thousands of man hours. The receiving unit is main AC powered hence a backup battery is needed.The proposed system by Amsaveni et al. [34,36] performs the automatic control action once there is the detection of 0.001 percent leakage of LPG. this automatic control action will offer a mechanical handle in

closing the valve and switching off the electric power supply into the house. and also through GSM, an alert message is sent to the users and a buzzer is given to inform the neighbours about the leakage. Soundarya [35] ATmega328P is the base of the system. The gas sensor MQ6 output and load cell are the ones used as inputs fed to the microchip. The result of the controller is provided to the simcom300 and LCD display. The ATmega328p receives the Output of gas sensor, so the priority of leakage detection is the first. Analog to digital converter amplifies and digitizes the weight sensor and passes on to the port pins of controller. GSM has two pins; the receiver and the transmitter pins and are attached to the ATmega328p. The controller has been provided to the protection circuitry exhaust fan. Selvi [38] proposed a project which is develop liquefied petroleum gas leakage detection and monitoring system. This is composed of two sensing unit, two varieties of alarm alert and online monitoring system. Gas leakage is detected by gas sensor that is specified to LPG gas and gas cylinder is weighed by load cell sensor. Only gas detection has a physical alert alarm using buzzer and the non-physical alert alarm which is using the sending of notification and email to the user through smartphone are developed to supply the system with Internet of Thing (IoT) technology. Rajeshwari [41] proposed system, Once the leakage of LPG has already begun, the leakage through a sensing of the output of the sensor is provided to the controller where the program is provided to check the leakage status. Running the motor with the help of the driver IC. After controlling the leakage message is transmitted to fire station through GSM then the buzzer warning tone towards the neighbour is provided and electric power supply is switched off through a relay.

Ayesha et *al*. [43-46, 49] designed for LPG gas leakage monitoring and Alert System using Arduino with MQ135 sensor. In this circuit, there is MQ135 gas sensor, microcontroller, buzzer, display and GSM. The sensor sense the leakage of the gas and send the signal to the microcontroller. The microcontroller issues a decision based on those information and then it sends a warning message on the screen and the message will appear on the user via GSM.However, there is no integration of optional power supply in case there is no electric power supply available. Evalina [47] designed system takes two major part by hardware module and software module, Schematic diagram is used to design the hardware module, C-language to develop the software module and once the gas leaks the gas sensor will detect the gas leak and then provide certain value of voltage in the sensor output. In particular when the output voltage of the curtain has reached the limit value of the specified value (settings) then the latter will automatically activate the microcontroller to

turn on the Buzzer to make the sound with a view to alerting the people nearest the place with an indication on the LCD screen of the device.

Dewi [48] proposed method uses two or more gas sensors to detect leakage in two or more locations around the gas tube and its distribution line. WSN system operates under gas sensor MQ-6 and wireless module Bluetooth HC-05. In case of the gas leakage the sensor transmits its data bidirectionally back to Arduino. Then explosion prevention system is switched on. The system will activate the alarm/buzzer, automatically release gas regulator and deactivate the air using the exhaust fan. Apeh [50] designed a system that detects gas leakage and alerts the subscriber through alarm and status display besides turning off the gas supply valve as a primary safety measure. Nadia [52] a smart system contain necessary sensors for detecting gas leakage. It identifies leakage of gases and display the findings in the LCD. Upon the detection of a leakage of any gas in a room or where the equipments are located, it will give it an alert through GSM Network, it detects the leak based on the preset threshold.

Ravi [53] proposed system used MQ6 gas sensor to measure the concentration of gas. It also sounds alarm in case of a gas leakage and cuts off the main power supply by sending message to the user. The weight of cylinder is measured with the help of load cell. In case of gas leakage it switches buzzer and a message is passed to user. Nagib [54] approached a device for detecting and monitoring LPG detection. It uses a Node MCU development board that is used as a controller. LPG detection occurs using MQ5, MQ6 gas sensors. The temperature and humidity is monitored with Dht11 sensor. All the data of sensors are posted in web server. This information can be accessed remotely by any user provided he has the internet connection or even without the internet within the wifi range of Node MCU at no cost. Sriwati [55, 56] proposed system works by detecting levels of LPG gas which is in the room source/engine using LPG gas. If there is a LPG gas is detected, the leakage indicator light will turn on the appropriate level. if the leak continues to rise, then try to flutter exhaust fan to reduce the levels of LPG in the room. Rakibul [57, 60] proposed system comprises Arduino Uno, and some sensing devices, which were installed in the kitchen. A cloud server (Ubidots) was related to this system by using Wi-Fi networks as carrier mediums. When the gas leakage was detected, liquid crystal display (LCD), and the buzzer were switched on and at that point a GPS sensor had tracked the location of the concerned area and it sent data to the user, police station and finally to the main power

circuit in the home, which was tripped off and the exhaust fan was turned on in order to prevent further accidents.

The proposed method suggested by Zaw Lin [58] is made up of gas leakage detection module, weighing system of gas cylinder, alert system, microcontroller, IoT system to register gas consumption, and SMS based cloud based communications platform. Kishor [59, 63, 65] designed a system used Internet of things which enabled LPG leakage detection and monitoring system. It is sensitive to reveal the gas leakage and has the capability of auto control of the stove knobs as well as the regulator knobs fitted. The leakage is reported by sending SMS to the user and further on the personnel of maintenance. It is detected by using a gas sensor that is sensitive to gases like butane and propane and thus the leakage is detected. The knobs and the regulator valve of the stove were controlled by using stepper motors. Afsana [61] proposed system, used gas sensor and fire sensor which are interfaced to the Arduino microcontroller. A response of each of these sensors can be observed in LCD -display. GSM module employs orders of delivery of SMS.

Rajapaksha [64] designed system, which automatically runs when the LPG concentration gets to a level of 200 PPM which is way below the concentration of LPG gas in inflammable form. The leakages were detected by the MQ-5 gas sensor and then given to the microcontroller. A warning signal will be automatically transmitted to the consumers and the circuit will be fitted with other gas sensors which are mounted on the electrical switches which are close to the gas cylinder and are left connected to the Bluetooth module to switch the electrical power off to avoid any spark. Israa [66] proposed system, An alert is relayed to the user when the gas has gone above a set level at which the user is able to remotely shut down the gas valve. It can also enable an exhaust fan, buzzer and sprinkler to take care of the hazards. Safe detection of gas leakage is very important because there may be dangers of fumes of stored LPG resulting to explosion and fire thus risking lives and property. Haryanto [67] proposed smart controlling system for kitchen fire protection based Internet of Things. Data that comes to temperature sensor, smoke sensor and human sensor was sent to the server and thus user will be able to access it through their smart phone. In case of dangerous condition, a warning signal can be provided to the smartphone of the user and the user can control the stove and the lid of LPG utilizing the application in his/her smart phone. The system proposed by Ivan [68] is based on the use of the primary sensor MQ-6 and sensors DHT22 that will help to record gas concentration and

room temperature, the protection system has an exhaust that acts as a fresh air in the room and a buzzer that serves as a direct warning alarm and water pump that stops a fire. Sinagal [93] constructed system to test the performance of servo motors in the opening and closing of the regulator lever with an emphasis on reliability of the operations. In the meantime, evaluating the responsiveness of the servo motors to detecting LPG leakages is meant to determine how effective the system can be in the event of an emergency. This study pays attention to the subsystem of Regulator Automation only. Kommy [94] proposed gas detector system that operates collaboratively with a mobile application was designed to achieve domestic fire control. The design process only gas leakage detector system. Not integrated emergency ventilation control system and an electrical power supply control system.

Darus [95] developed a LPG Regulator, it addresses the problem of LPG gas-related fires and detect gas leakages in the rubber hoses of gas stoves that are widely used in the kitchens. The gadget can perfectly be used by all property owners since it will automatically open the LPG cylinder valve in case a gas leak occurs. Nobody lives in the house; hence, fire might occur because of internal gas leaks that could not be noted. The lack of inhabitants does not turn into a factor of the appearance of fires anymore with the help of this device. Detection of gas leakage is the task of Baban [96] proposed systems. In case value of gas measured by sensor is greater than Normal value then IoT Processor sends message (LD i.e. leakage detected) to user through web server. Through a web or mobile application, user can ask the LPG regulator switch to be closed. After receiving instructions by user IoT Processor controls regulator switch in switch control module. In case of leakage of the gas where the leakage would exceed the critical level then controller turn of regulator should be switched off immediately followed by the sending of alarms to the user to prevent accident. Saleh [98] designed and implementation of a smart gas leak detection system based on Arduino. An Arduino Uno microcontroller with an MQ6 sensor was used to detect gas leakage, an air fan motor to reduce gas concentration by ventilating the air, and GSM as a wireless communication method to notify users via SMS. Senthil [99] Proposed system is cut off the gas supply using an automated shutting off device, leak is detected, consumers will be notified through S MS via GSM, location using GPRS, and will be able to resolve the situation as quickly as feasible. Tina [100] proposed system the Internet of Things-based smart gas leakage detection and alert system that helps to detect and notify the consumers about gas leakages in real-time. In this case, we are coming up

with an alert system, which is compatible with Internet of Things and sends messages to the device of the user. It is quite an innovative approach. Besides, we are incorporating a web feature code which enables the user to use a real time data base to view data through real time application. Siti [101] studied a detection and monitor LPG leakage technique and corresponded safety device to countermeasure the gas leaking issue in order the ensure the safety. Secondary data method has been applied in data collecting from the previous research. Also mentioned further research is required on different approaches to providing a warning to users to reduce the number of gas accidents. One of the positive things about this is the researcher's awareness of developing gas leakage detection, monitoring and safety systems. It was reflected that the amount of research that has been conducted in this area. So gas leakage detection and monitoring and prevention system development is very Crucial. However, All of this study focuses only primarily on detection and lacks of automatic preventive mechanisms such as ventilation activation or gas valve control. Our proposed work we have integrated leakage detection, multistage prevention system and optional power supply when no electric/supply power is available. Because No signal/alert/ short message service (sms) will be sent except continuous power supply. Future research could refine the gas safety module, incorporating more automated preventive actions and enhancing scalability for diverse applications.

2.3 Conclusion

The reviewed literature demonstrates significant progress in IoT-based gas safety systems, with diverse approaches employing microcontrollers, sensors, and communication modules. While many studies have achieved reliable detection and alerting mechanisms, most lack integrated multistage prevention features, scalability for industrial applications, and cloud-based analytics. By addressing these gaps, future research can improve the robustness and applicability of gas safety systems in various settings. This review establishes a strong foundation for advancing smart gas monitoring technologies, aligning with the increasing need for comprehensive, IoT-enabled safety solutions in energy-dependent environment.

Chapter 03

Methodology

3.1 Introduction

The first part of the methodology presents the hardware design and components of the proposed system. Then the software design process and implementation is thoroughly discussed. Then the system overflow is discussed with the objectives clarification of this study. Additionally, the electrical simulation using proteus is also presented at the end of this chapter.

3.2 System Workflow

In the operation of the smart gas leakage detection, monitoring, and multistage prevention system is a comprehensive and sequential process that integrates continuous monitoring, precise detection, automated preventive actions, and user-friendly visualization. Each stage is meticulously designed to ensure the system's reliability, responsiveness, and ability to mitigate risks effectively. This workflow, driven by the ESP8266 microcontroller and IoT integration, functions seamlessly across four critical stages: monitoring, detection, prevention, and visualization.

3.2.1 Monitoring Stage

At the core of the monitoring process is the MQ6 gas sensor, which continuously analyzes the air for the presence of LPG (Liquefied Petroleum Gas). Strategically placed near the gas cylinder, the MQ6 sensor detects propane and butane vapors, generating analog signals that are directly proportional to the gas concentration in parts per million (ppm). These signals are transmitted to the ESP8266 microcontroller, which processes the data in real time. The sensor's sensitivity allows it to identify even minute gas leaks, providing an early warning system to prevent dangerous accumulations.

Simultaneously, the load cell, paired with an HX711 amplifier, tracks the weight of the gas cylinder. This component is integral to monitoring the remaining gas volume, offering a proactive measure to notify users when the cylinder nears depletion. The load cell's data, converted to digital signals by the HX711, is continuously processed by the ESP8266 to ensure accurate and up-to-date information. The monitoring stage operates autonomously, with all data streams feeding into the microcontroller for real-time analysis and decision-

making. This stage forms the foundation of the system, ensuring that any deviations in normal conditions are promptly identified.

3.2.2 Detection Stage

The detection stage is initiated when the MQ6 sensor identifies gas concentrations that exceed the predefined first threshold. This threshold, set at a safe level below hazardous concentrations, acts as a trigger for the system to notify users of a potential gas leak. The ESP8266 microcontroller processes the sensor's signals and promptly sends an alert to the Blynk app via a Wi-Fi connection. The alert, displayed on the user's smartphone, includes details about the detected gas concentration and advises immediate attention to the situation.

This stage highlights the importance of early detection in preventing accidents. By providing real-time notifications, the system empowers users to assess the severity of the situation and take preliminary actions if necessary. The system is programmed to ensure that the detection process is not affected by false alarms or environmental noise, such as cooking fumes or minor fluctuations in gas levels. This is achieved through calibration of the MQ6 sensor and algorithms within the ESP8266 firmware that filter out anomalies. The detection stage bridges the gap between continuous monitoring and active prevention, ensuring that users are informed as soon as potential risks are identified.

3.2.3 Prevention Stage

The prevention stage is the most critical phase of the system, designed to actively mitigate risks and prevent the escalation of a gas leak. When gas concentration exceeds the second predefined threshold indicating a potentially dangerous level the ESP8266 microcontroller triggers a series of automated safety actions.

The first preventive measure involves the servo motor, which is programmed to close the gas regulator. This immediate action cuts off the gas supply, effectively stopping further leakage at its source. The servo motor, controlled by precise signals from the ESP8266, ensures reliable operation under various conditions. Its high torque and accuracy are critical for securely shutting off the regulator, even in challenging scenarios. In conjunction with the servo motor, the exhaust fan is activated to disperse accumulated gas and maintain indoor air quality. Positioned strategically within the area, the fan works to lower the gas concentration to safe levels by increasing ventilation. The fan's operation is particularly important in enclosed spaces, where gas accumulation poses a heightened risk

of ignition. The coordinated activation of the servo motor and exhaust fan exemplifies the system's multistage prevention approach, addressing both the source of the leak and its potential consequences. The prevention stage is designed to operate autonomously, minimizing the need for user intervention during critical situations. By combining mechanical actions with electronic controls, the system ensures a comprehensive response to gas leaks, significantly reducing the likelihood of accidents such as fires or explosions.

3.2.4 Visualization Stage

The final stage of the workflow focuses on providing real-time visualization and user interaction through the Blynk app. The app serves as the interface between the system and the user, offering a clear and intuitive platform for monitoring system status and receiving alerts. The Blynk app displays key data points, including gas concentration levels, cylinder weight, and the status of safety mechanisms such as the servo motor and exhaust fan. This real-time information allows users to stay informed about the system's performance and take additional actions if necessary. For instance, users can manually activate or deactivate the exhaust fan through the app, providing an extra layer of control.

Visualization through the app is not limited to current conditions; it also includes data logging and trend analysis. The system records gas concentration fluctuations and weight changes over time, enabling users to identify patterns and optimize gas usage. Notifications sent via the app are designed to be non-intrusive yet attention-grabbing, ensuring that critical alerts are not overlooked. The app's integration with the ESP8266 microcontroller is achieved through MQTT protocols, ensuring secure and reliable data transfer. The visualization stage completes the workflow by keeping users engaged and informed. It transforms the system from a purely automated solution into an interactive tool, empowering users to take proactive steps in maintaining safety and efficiency.

The overall block diagram of the whole process in now given below in Fig 3.1. This block diagram illustrates of an IoT-based smart, automated safety system that detects LPG leakage, alerts users both locally and remotely, and activates protective measures to prevent accidents. Power Supply provides the necessary electrical power to all components of the system. Gas Sensor detects the presence of LPG in the air and sends the signal to the NodeMCU IoT Board. Load Cell connected through a Signal Amplifier, measures the weight of the LPG cylinder to monitor gas usage and detect potential leaks

through weight loss. The NodeMCU IoT Board serves as the central controller, processing inputs from the gas sensor and load cell.

The system provides local alerts via:

LCD Display – shows gas levels, cylinder weight, and system status.

Buzzer – sounds an alarm when gas leakage is detected.

It also takes automatic safety actions via:

Relay Module with Servo Motor – can shut off the gas supply.

Relay Module with Exhaust Fan – activates ventilation to remove leaked gas.

Through Wi-Fi, the NodeMCU sends real-time alerts to the user via SMS, enabling remote monitoring and timely response.

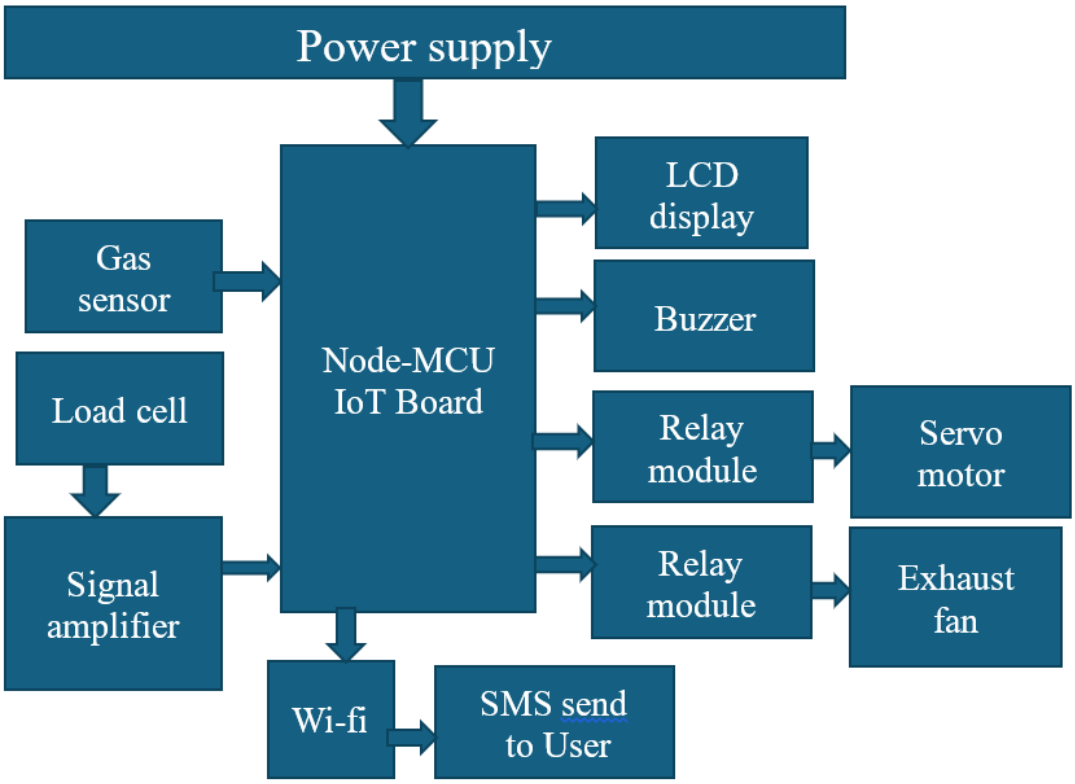


Fig. 3.1: Block Diagram of gas leakage detection, monitoring and multistage prevention system

Additionally, the flowchart of the whole system is now given below in Fig 3.2. this flowchart summarizes the working process of the LPG leakage detection system: When gas leakage occurs, sensors detect it and send signals to the microcontroller. The system then activates relays to shut down the main power supply, rotates a servo motor to close the cylinder valve, turns on the exhaust fan, sounds a buzzer to alert users, and sends SMS notifications. These actions stop the leakage and ensure safety.

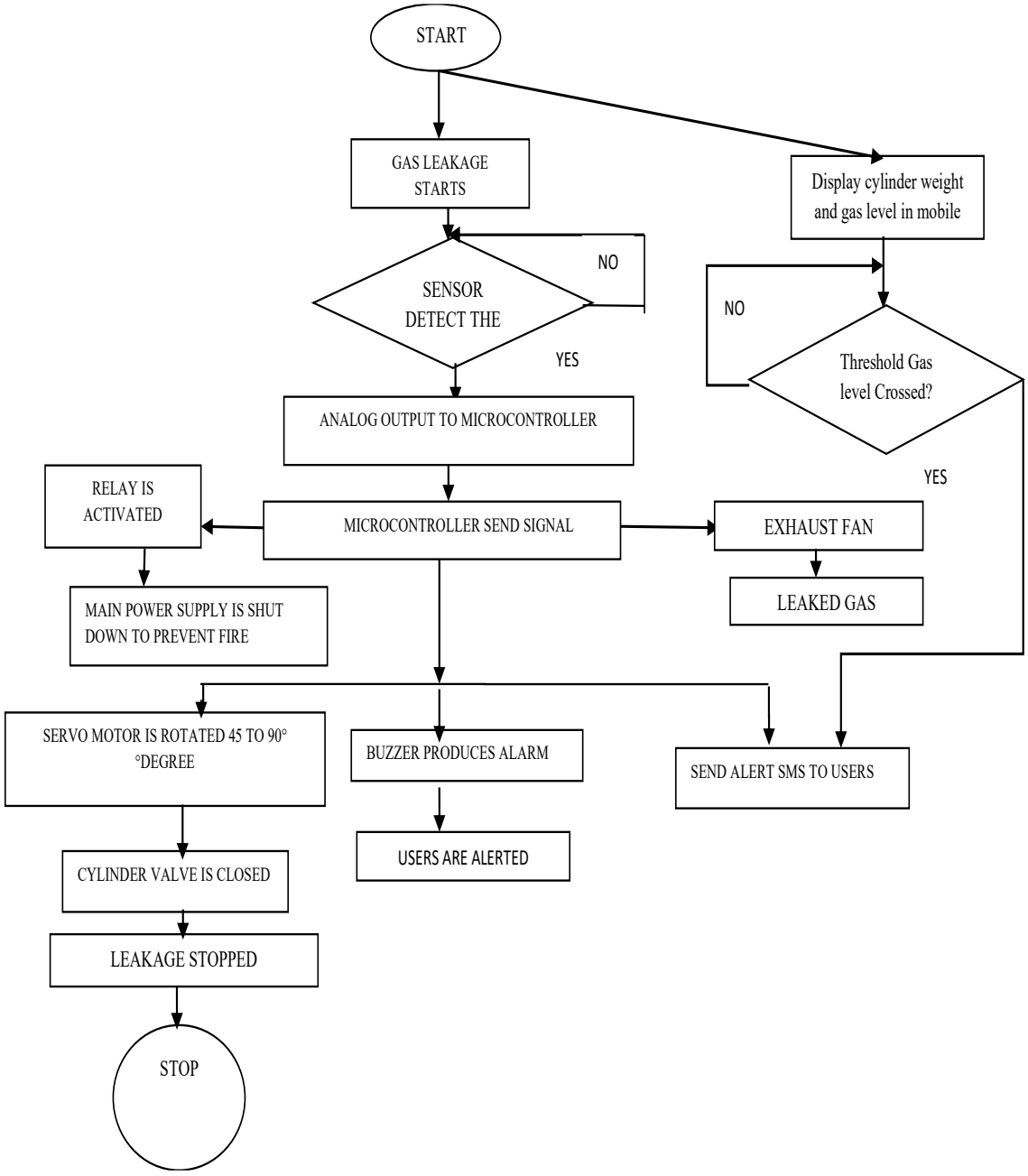


Fig. 3. 2: Flowchart of the proposed smart gas leakage detection, monitoring and multistage prevention system

3.2.5 Overall System Coordination

The workflow is structured to ensure seamless coordination across all stages. The ESP8266 microcontroller acts as the central hub, processing data from the MQ6 sensor and load cell, controlling the servo motor and exhaust fan, and communicating with the Blynk app. Each stage is interconnected, allowing the system to transition smoothly from monitoring to detection, prevention, and visualization. This coordination minimizes response time and maximizes the effectiveness of safety measures.

The workflow's design prioritizes both automation and user involvement, striking a balance that ensures comprehensive protection without unnecessary complexity. By addressing potential risks at multiple levels early detection, active prevention, and real-time visualization the system provides a robust and reliable solution for managing gas safety in residential and industrial settings.

3.2.6 Protection from sudden major gas leakage using auto shut-off valve/device :

Auto shut-off devices enhance user safety, efficiency and convenience across various applications. As technology progresses, these devices are likely to become even more sophisticated and prevalent in maintaining safety standard. The following instruments needed to implementation the sudden major gas leakage protection system.

LPG Cylinder:

LPG cylinder is a reliable and effective way of storing of liquefied petroleum gas. The LPG is liquefied so as to maximize its storing potential since a liter of LPG has been found to be equivalent to 270 litres of natural gas. It is needed to be cooled and pressurized to the right conditions of temperature and pressure in order to be liquefied and this needs to be done during its storage and possibly transportation as well. To this end make use of LPG Cylinder. LPG is a gas liquefied. Thus, the pressure within the cylinder will change to the same throughout its capacity until the vaporistion of the final liquid form of LPG within the containers. Then the pressure will be lowered, and the final LPG vapour will be utilized. LPG cylinder normally consists of welded steel, aluminium or composites. The most common of them all is steel, because it can be easily fabricated and also it is a low cost material. Others made of aluminium or composites to reduce mass are cylinders. The latest invention is the composite cylinder. These are usually fibre glass and high impact high plastic shell [86].

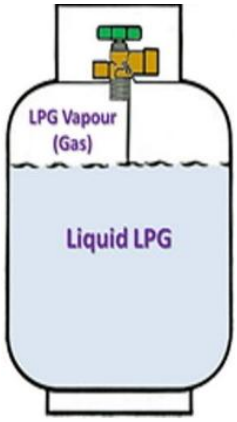


Fig.3.3: Inside view of LPG cylinder

Quick Coupling valve with PRV:

In LPG cylinder, the only extremely important safety feature is the pressure relief valve. Pressure relief valves are meant to relieve the extra pressure which may have potential to occur due to overfilling or be in excess of extreme heat or fire. A pressure relief valve works to ensure that a cylinder is not destroyed by the unlikely occurrence of too much pressure. The pressure relief valves are pushed into the shut state by the strength of a strong spring inside. The valve will continue to be closed as long as the pressure is not exceeding that of the spring.

Inlet dia ¾ inch , Outlet 22 mm, prv 26 bar, flow capacity 5m3/min .

LPG Regulator:

The main job of LPG gas regulator is to regulated the LPG gas pressure which is high i.e. 400-1200kPa (4-12 bar) to the house-hold required working pressure of the gas appliances 2.75kPa (27.5 ml bar). The pressure of the gas bottle is dependent on temperature, whereas LPG gas regulator should ensure the pressure is constantly 2.75kPa. LPG is fed into the regulator via the inlet port and the pressure of LPG is adjusted through a spring loaded diaphragm. There are changes in pressure which cause the diaphragm to move thereby opening the inlet valve. The pressure in an LPG gas bottle will be 400-1200 kPa as compared to 2.75 kPa LPG gas regulator, the commonly needed gas pressure of LPG gas appliances. A regulator is used in connection to LPG where there is automatic reduction of high pressure gas within a gas cylinder into required pressure. This automatically happens with the help of a diaphragm and springs [86].

3.2.6.1 Perfomance test of auto shut-off valve/device:

Auto shut-off device which can automatically shut-off the gas flow from the cylinder and safe from sudden fire accident due to major leakages (above 50,000 PPM) in case of rupturing/damages of hose pipe. Auto shut off valve installed top on LPG cylinder and below the LPG regulator, The safety mechanism designed to stop the flow of LPG in case of leakage, excessive flow, or disconnection of the regulator. Its working principle is based on pressure, flow, and mechanical valves show in Fig.3.4 and Fig.3.6

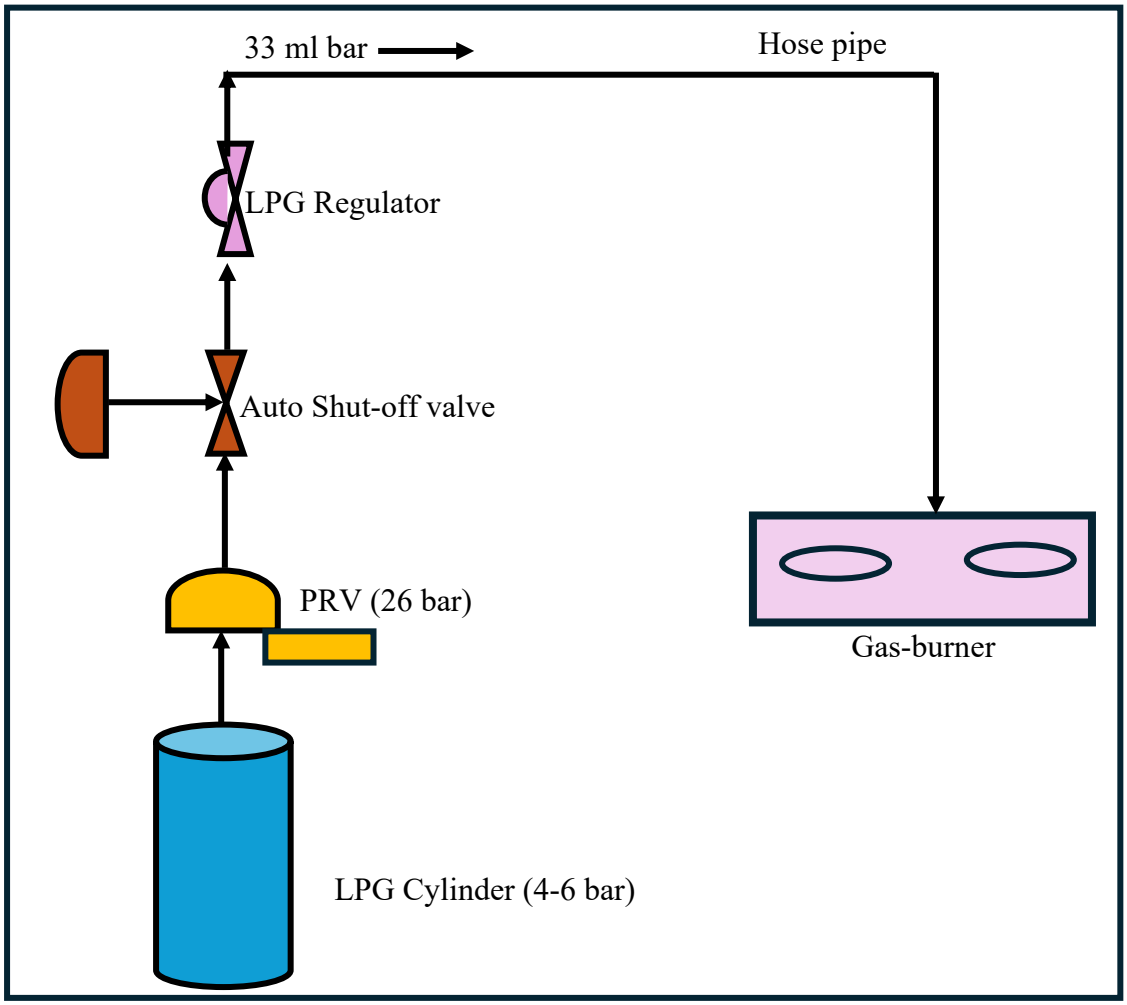


Fig.3.4**:** Flow diagram of using auto shut-off valve

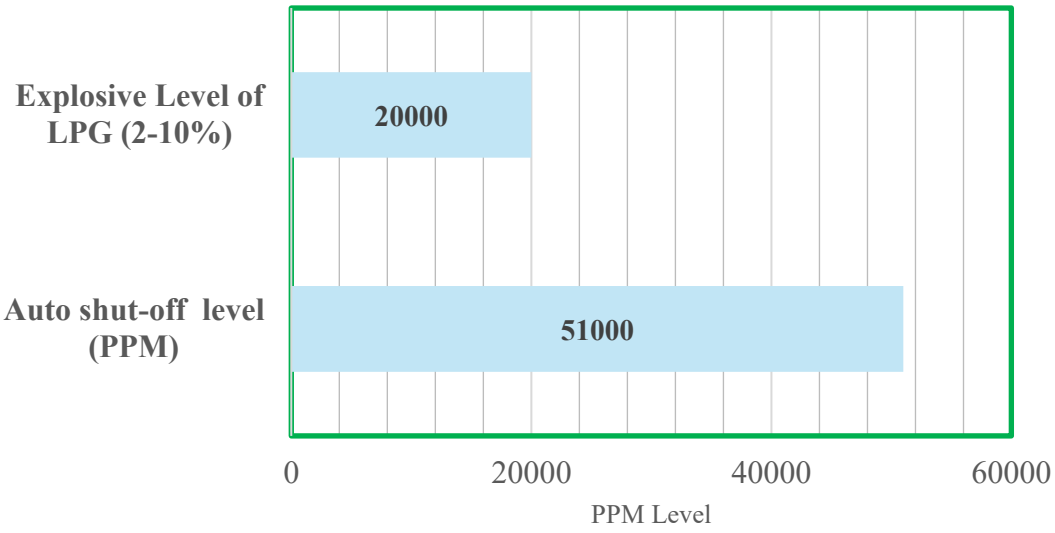


Fig.3.5: Performance chart of marketed Auto shut off device

3.2.7 Key Components of auto shut-off valve:

Auto shut-off valve is a safety device used in liquefied petroleum gas (LPG) systems to automatically stop the gas flow in case of a leak, overpressure, or equipment failure. It helps prevent gas-related accidents by shutting off the gas supply when abnormal conditions are detected, such as a sudden drop in pressure or flame failure. These valves are commonly used in gas cylinders, pipelines, and appliances to enhance safety and ensure controlled gas usage.

Flow Sensor/Valve- Monitors the gas flow rate.
Pressure Sensor- Detects abnormal pressure changes.
Spring Mechanism- Controls the valve position based on pressure.
Shut-off Valve- Stops the gas flow in case of irregularities.

Working Principle

Normal Operation**:** When the gas flow and pressure are within normal limits, the shut-off valve remains open, allowing the gas to pass through to the connected appliance.

Abnormal Flow or Leakage**:** If there is a sudden increase in gas flow (e.g., due to a pipe rupture or leak), the flow sensor detects it. The change triggers the spring-loaded valve, which closes the gas supply to prevent further leakage.

Regulator Disconnection**:** If the regulator gets disconnected accidentally, the pressure sensor detects a drop in pressure. The valve immediately shuts off the gas flow to prevent release into the environment.

Manual Reset**:** After the shut-off device is triggered, the system typically requires manual intervention to reset it. This ensures the issue is resolved before resuming gas flow.



Fig.3.6: Using auto shut-off valve/device (Real Device)

Now, we did a setup to measure the cut- off pressure of Auto shut off device which is shown in Figure 3.7



Fig 3.7: Arrangement for cut- off pressure measure of Auto shut off device

Now the observations from Fig 3.9, which is shown in Table 3.1

3.2.7.1 Observations:

1. **Pressure Drop with Burner On:**
    - At each measurement stage, pressure slightly drops when the burner is on, which is expected due to gas flow/demand during combustion.
    - Typical pressure drop is about **1,0 mm H_2O (1 ml bar)** per stage when the burner is operating.
2. **Effect of Auto Shut-off Device:**
    - The auto shut-off device introduces a drop of 312 mm and 302 mm H_2O (30.59 ml bar and 29.61 ml bar) in burner off and on conditions.
    - This pressure drop is due to flow restrictions or design calibration for safety.
3. **Safety Margin:**
    - The cut-off pressures (312mm and 302 mm H_2O) are Lower the working pressure for most domestic LPG appliances, indicating safe operation.
    - The cut-off threshold provides a good buffer below operating pressure.

Table 3.1: Cut-off Pressure Measurements of auto shut-off device (in mm of water & ml bar).

Measurement Stage	Burner Off Condition	Burner On Condition
Pressure after only LPG regulator	370 mm H_2O (36 ml bar)	360 mm H_2O (35 ml bar)
Pressure after LPG regulator with auto shut-off	337 mm H_2O (33 ml bar)	328 mm H_2O (32 ml bar)
Cut-off pressure of auto shut-off device	312 mm H_2O (30.59 ml bar)	302 mm H_2O (29.61 ml bar)

3.3 Hardware Design and Components

This section of the thesis defines all the hardware design and the components that are used in this study.

3.3.1 Microcontroller (ESP8266)

The ESP8266 Fig 3.8 acts as the central processing unit of the system, coordinating data from sensors, controlling actuators, and establishing IoT integration through Wi-Fi. Its compact design, cost-effectiveness, and compatibility with IoT platforms make it the ideal choice for this application.

The ESP8266 features multiple GPIO pins to interface with various sensors and actuators, including the MQ6 sensor, servo motor, load cell, and exhaust fan. Its built-in Wi-Fi capability facilitates seamless data transmission to the Blynk app, allowing for real-time monitoring and control. Additionally, its energy-efficient operation is crucial for continuous monitoring in a residential setup. The microcontroller processes analog signals from the MQ6 gas sensor and digital signals from the HX711 amplifier connected to the load cell, converting them into actionable data.Threshold-based programming enables the ESP8266 to trigger safety actions such as closing the gas regulator and activating the exhaust fan when critical gas concentration levels are detected.



Fig.3.8: Microcontroller (ESP8266)

Technical Specifications:

Power input	4.5V ~ 9V (10VMAX), USB-powered
Transfer rate (sending sensor data)	110-460800bps (bits per second)
Support UART	GPIO data communication interface
Working temperature	-40°C ~ + 125°C
Drive Type	Dual High-Power H-Bridge
Flash Size	4MByte

3.3.2 Gas Sensor (MQ6):

The MQ6 gas sensor fig.3.9 is a highly sensitive device designed to detect LPG (Liquefied Petroleum Gas), specifically propane and butane, in the air. It operates by measuring the concentration of gases in parts per million (ppm) and transmitting an analog signal

corresponding to the detected level to the ESP8266 microcontroller. The MQ6 sensor is essential for providing the primary input for leak detection and initiating safety responses. The MQ6 sensor's sensitivity ranges from 200 ppm to 10,000 ppm for LPG, making it suitable for both early detection and higher concentration scenarios. The sensor operates on a 5V DC power supply, with a typical current consumption of 150 mA during active measurement.

Internally, the sensor consists of a tin dioxide (SnO_2) sensing layer that changes resistance when exposed to hydrocarbons like propane and butane, ensuring precise and reliable readings. Strategic placement of the MQ6 sensor near the gas cylinder ensures that even minor leaks are detected swiftly. The sensor is calibrated to differentiate between ambient background gas levels and hazardous concentrations. The system uses two distinct thresholds: the first triggers a notification via the Blynk app to alert users, while the second initiates automated safety mechanisms, including activating the exhaust fan and shutting off the gas regulator. This dual-threshold approach enhances safety by addressing potential leaks before they escalate into emergencies. The MQ6's reliability, affordability, and broad detection range make it a vital component of the system.



Fig.3.9 : Gas Sensor (MQ6)

Technical Specifications of MQ6:

- Model: MQ-6
- Operating Voltage: 5V DC
- Detecting Range:200-10000 ppm
- Relative Humidity:<95% RH

3.3.3 Servo Motor

The servo motor is a critical actuator used to automatically close the gas regulator in the event of a detected leak, ensuring immediate action to prevent further leakage. The motor

operates based on control signals sent by the ESP8266 microcontroller, which determine its rotation angle with high precision. This functionality is essential for eliminating the source of the leak and reducing the risk of fire or explosion.

Fig. 3.10 the servo motor chosen for this system is a Tower Pro MG995, known for its durability and high torque of up to 9.4 kg·cm at 6V, making it capable of handling the mechanical operation of closing a gas regulator under various conditions. It operates at a voltage range of 4.8V to 6V and has a rotation angle of 0° to 180°, which is sufficient for securely shutting off the regulator. The motor's positioning accuracy is facilitated by a built-in control circuit and potentiometer, allowing precise adjustments based on feedback from the ESP8266. The servo motor's responsiveness is critical in scenarios where rapid closure of the gas regulator is necessary to prevent the escalation of a leak. Its integration into the system ensures that preventive actions are executed reliably and without delay.

Additionally, the motor's compact design and low power consumption make it suitable for residential applications.

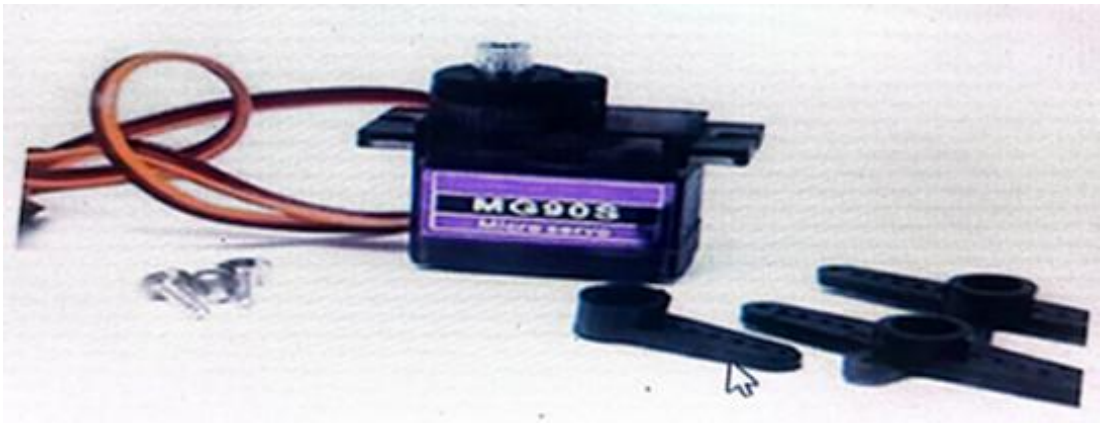


Fig. 3.10: Photograph of Servo Motor

3.3.4 Exhaust Fan

The exhaust fan plays a vital role in maintaining air quality by dispersing accumulated gas from the environment. When the gas concentration exceeds the secondary threshold, the fan is automatically activated by the ESP8266.

This component is strategically installed to ensure efficient ventilation in the vicinity of the gas cylinder. Its operation reduces the likelihood of gas ignition by lowering the concentration of leaked gas in the air. The exhaust fan operates in conjunction with other

safety mechanisms, such as the servo motor, to provide a comprehensive multistage response to gas leaks.

3.3.5 Weight Measurement System (Load Cell)

The load cell, integrated with an HX711 amplifier, is responsible for continuously measuring the weight of the gas cylinder and providing real-time data on the remaining gas volume. This feature enhances user convenience by notifying them via the Blynk app when the cylinder is nearing depletion, allowing timely replacements.The load cell used is a 4-wire strain gauge sensor with a maximum capacity of 50 kg, ensuring compatibility with standard LPG cylinders. The HX711 amplifier, operating at 2.7V to 5.5V, converts the analog signals from the load cell into precise digital data that is processed by the ESP8266. The system is calibrated to account for environmental factors such as vibrations or uneven surfaces, minimizing errors in weight measurement.This functionality provides users with regular updates on cylinder weight, ensuring uninterrupted gas supply. The integration of the load cell into the system adds an extra layer of utility, making it a comprehensive monitoring solution beyond just safety.

3.3.6 Power Supply

The system is powered by a 5V DC power supply, which provides stable and consistent energy to all components. A step-down voltage regulator is employed to ensure that the ESP8266 and connected sensors operate within their optimal voltage ranges. The power supply design also includes protection mechanisms against voltage fluctuations to enhance the system's reliability.

A LiPo (Lithium Polymer) rechargeable battery we have used also for power supply when no power supply at home or gas concentration reached to threshold level and auto shut off power supply then system will run by this power source and send signals.

3.4 Software Design and Components

The software design of the smart gas leakage detection and monitoring system forms the backbone of its functionality, integrating IoT communication, sensor data processing, and actuator control. This section elaborates on the Blynk app as the primary user interface, the Arduino IDE as the programming environment, and the use of Proteus software for

electrical simulation and validation. By combining these tools and platforms, the system achieves reliability, real-time interaction, and user-friendly operation.

The circuit simulation diagram is now given below-

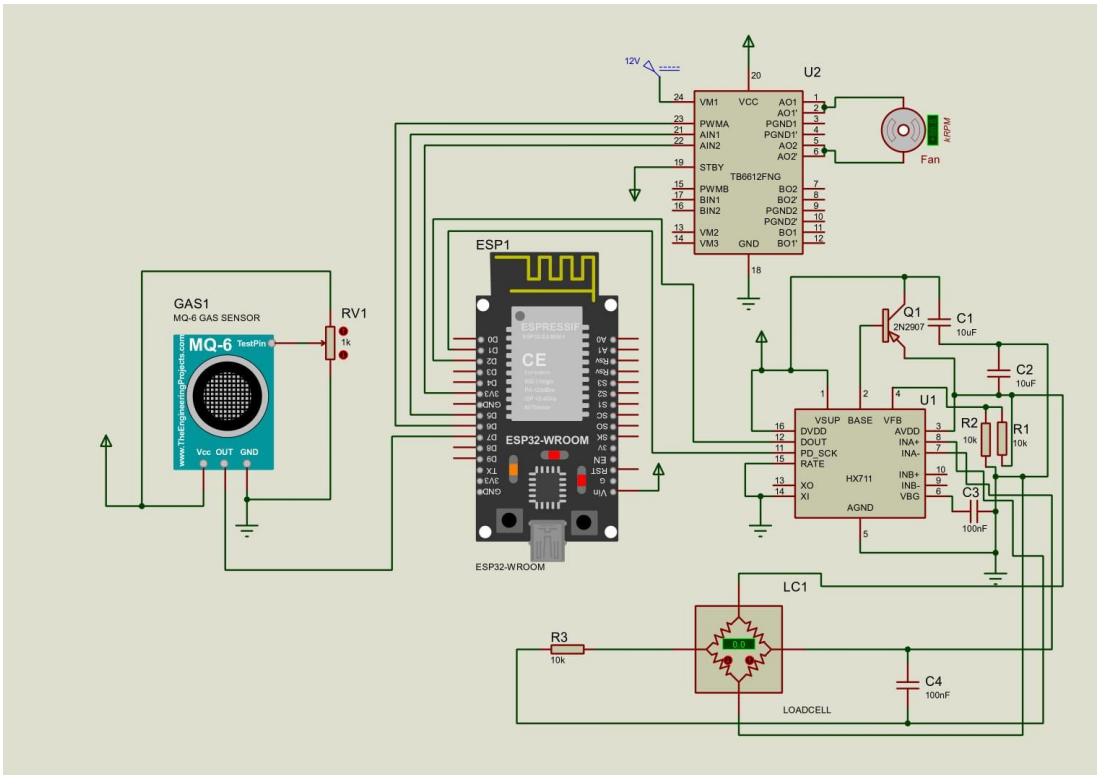


Fig.3.11: Integration of the whole circuit in Proteus

3.4.1 IoT Integration (Blynk App)

The Blynk app acts as the user interface for monitoring and controlling the system. It provides real-time data visualization, allowing users to track key parameters such as gas concentration levels, cylinder weight, and the operational status of safety mechanisms like the exhaust fan and servo motor. The app also enables remote control, allowing users to manually activate or deactivate the fan and motor if needed. Furthermore, the Blynk app generates immediate notifications in the event of a gas leak, giving users the ability to respond quickly and minimize risks. The app communicates with the ESP8266 microcontroller via Wi-Fi, utilizing the MQTT (Message Queuing Telemetry Transport) protocol for efficient and secure data transfer. MQTT is a lightweight, publish-subscribe messaging protocol widely used in IoT systems for its low bandwidth requirements and robust performance.

The ESP8266 acts as the publisher, sending real-time data to the Blynk server, while the app functions as the subscriber, receiving and displaying the data. The Blynk app's graphical interface is intuitive and customizable. Widgets such as gauges, sliders, and graph plots are used to display gas concentration (in ppm), cylinder weight, and other system parameters. Push notifications alert users when gas levels exceed predefined thresholds, and logs are maintained to provide a history of system activity for better analysis and user insights. The app supports cross-platform compatibility, allowing it to run on Android, iOS, and web browsers.

Technical specifications of the Blynk server used in this system include its ability to handle multiple device connections, high data throughput, and end-to-end encryption, ensuring data security. The server maintains uptime for real-time operations and offers RESTful API integrations for enhanced functionality. By incorporating the Blynk app, the system achieves a seamless blend of automation and user interaction.

Fig.3.12 illustrates the broad range of IoT applications in modern life. It shows how IoT technology is being integrated into diverse fields including smart homes, offices, and cities; vehicle, asset, pet, and person monitoring; everyday consumer devices; mobile and embedded systems; energy consumption monitoring; agriculture automation; building management; healthcare and telemedicine; surveillance and security; and shopping malls. These applications demonstrate IoT's potential to enhance efficiency, safety, automation, and connectivity in both personal and industrial domains.

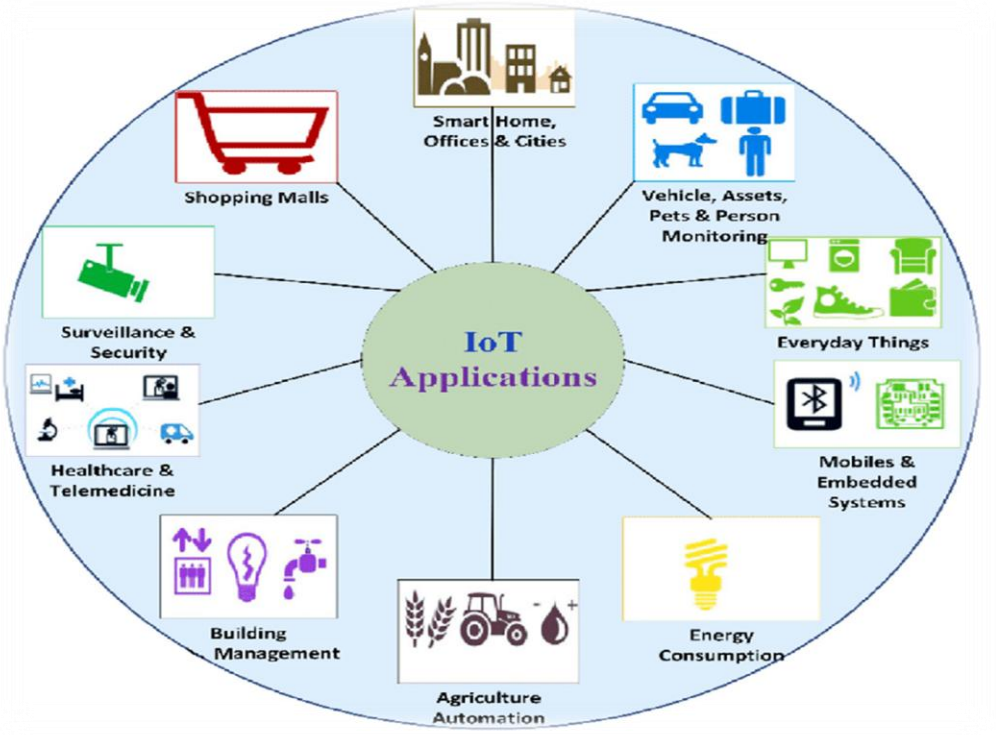


Fig.3.12 Monitoring and controlling by using IOT [102]

3.4.2 Programming

The system's firmware is developed using the Arduino IDE, a popular platform for programming microcontrollers like the ESP8266. The IDE provides a robust development environment, offering libraries, tools, and features to facilitate the integration of sensors, actuators, and IoT communication protocols.

a) Sensor Interfacing and Data Acquisition:

The MQ6 sensor outputs analog signals representing gas concentration in parts per million (ppm). The ESP8266's built-in ADC (Analog-to-Digital Converter) processes this input, mapping the sensor's voltage range (0–5V) to a ppm scale. Similarly, the HX711 amplifier converts analog weight data from the load cell into digital signals for precise processing. The code includes calibration routines to minimize errors and ensure accurate measurements.

b) Threshold Definitions:

Predefined thresholds for gas concentration and cylinder weight are incorporated into the firmware. The first threshold triggers an alert via the Blynk app, notifying users of a potential gas leak, while the second threshold activates safety actions such as the exhaust

fan and servo motor. These thresholds are determined based on safety standards and empirical testing.

c) Actuator Control:

The servo motor and exhaust fan are controlled via PWM (Pulse Width Modulation) signals generated by the ESP8266. The motor is programmed to rotate to a specific angle (e.g., 90° or 180°) to close the gas regulator, while the fan operates at variable speeds based on gas concentration levels. This ensures efficient operation and energy conservation.

d) IoT Communication:

Libraries such as Blynk Simple Esp8266 and PubSubClient are used to establish a connection between the ESP8266 and the Blynk app. MQTT protocols enable real-time data exchange with low latency, ensuring that users receive timely alerts and system updates.

e) Error Handling and Fail-Safe Mechanisms:

The firmware includes error-checking routines to detect sensor failures, communication issues, or power disruptions. For example, if the MQ6 sensor becomes unresponsive, the system defaults to activating the exhaust fan as a precautionary measure.

The technical specifications of the ESP8266 firmware include support for a flash memory size of 4MB, a clock speed of 80 MHz, and a Wi-Fi range of up to 150 meters in open conditions. The firmware is designed to execute real-time tasks with minimal delays, ensuring the system's reliability in critical scenarios.

3.5 Electrical Simulation (Proteus)

The electrical simulation of the system is performed in Proteus Design Suite, a powerful tool for circuit design, simulation, and testing. The simulation provides a virtual environment for validating the interactions between components such as the ESP8266, MQ6 sensor, servo motor, load cell, and exhaust fan. By modeling the system in Proteus, potential issues can be identified and addressed before physical implementation.

3.5.1 Gas Leakage Simulation

The MQ6 sensor is simulated by generating virtual gas inputs at varying concentrations. The Proteus model includes the sensor's analog response curve, which maps gas concentration (ppm) to output voltage. The ESP8266 processes these inputs and activates the servo motor and exhaust fan at the appropriate thresholds. The simulation verifies the

accuracy of the detection and prevention mechanisms, ensuring that the system responds correctly under different scenarios.

3.5.2 Load Cell Simulation

The load cell and HX711 amplifier are modeled to simulate weight changes in the gas cylinder. The Proteus environment generates variable analog inputs corresponding to cylinder weight, which are digitized by the HX711 and processed by the ESP8266. The simulation validates the load cell's accuracy and its integration with the Blynk app for real-time weight updates.

3.5.3 Alert Testing

The system's alert mechanisms, including notifications sent to the Blynk app and local alarms such as LEDs or buzzers, are tested under simulated conditions. For example, a simulated gas leak at 300 ppm triggers an alert notification and activated buzzer and exhaust fan. while a leak at 800 ppm activated servo motor and turn off the cylinder knob. The simulation ensures that all safety actions are executed as programmed. Technical specifications of Proteus simulation include support for real-time circuit interaction, SPICE-based modeling for accurate analog simulations, and virtual debugging tools for firmware testing. The simulation environment replicates the system's electrical behavior with high fidelity, ensuring that the design meets performance and safety standards.

3.6 Conclusion

The methodology chapter outlines the comprehensive design, development, and implementation processes of the smart gas leakage detection, monitoring, and multistage prevention system. By leveraging the ESP8266 microcontroller as the core processing unit, the system seamlessly integrates essential hardware components such as the MQ6 gas sensor, servo motor, exhaust fan, and load cell. Each of these components is carefully calibrated and strategically deployed to ensure accurate detection, timely prevention, and real-time monitoring of gas leaks.

The software design, featuring programming in the Arduino IDE and IoT integration via the Blynk app, enables remote monitoring, user-friendly interaction, and reliable communication. Threshold-based automation ensures that safety mechanisms are activated promptly in response to critical gas concentrations.

The use of MQTT protocols enhances the system's responsiveness, while the Blynk app serves as an intuitive interface for visualizing real-time data and controlling system functions. Electrical simulations performed in Proteus validate the functionality and reliability of the system, simulating various scenarios such as gas leaks, weight changes, and alert testing. These simulations provide critical insights into the performance of the hardware and software components, minimizing errors during physical implementation.

In conclusion, the methodology demonstrates the seamless integration of advanced hardware, robust software, and reliable simulation techniques to create a cost-effective and scalable IoT-enabled solution. This chapter establishes a strong foundation for the system’s deployment, addressing the critical need for enhanced gas safety in residential and industrial environments.

Chapter 04

Results and Discussion

4.1 Introduction

This chapter presents an in-depth analysis of the LPG detection system. First, the discussion will be on the results obtained from mQ6 sensor. Then the multistage protection system will be discussed and explained in brief. Lastly, the integration of the whole system is illustrated with the financial breakdown as this is a cost effective and efficient solution.

4.2 Implementation of gas leakage detection system

The MQ6 gas sensor implemented in the system has demonstrated a high level of accuracy in detecting different cases of gas leakage under varying conditions. During the testing phase, the sensor reliably identified fluctuations in gas levels and responded promptly when leakage occurred. The system was designed to collect and transmit real-time gas level data, along with other critical parameters such as cylinder weight, exhaust fan state, and system status, to the Blynk cloud server. This seamless integration with the Blynk IoT platform enabled efficient remote monitoring and ensured that all relevant data was logged and accessible for analysis.

One of the critical components of the system is its ability to trigger an immediate response when gas levels exceed a predefined threshold value. This threshold was set based on safety standards to ensure that even small leakages are detected early, reducing the risk of hazardous situations. Once the gas concentration crosses the set limit, the system activates a multi-stage response protocol. Initially, an email alert is sent to a predefined user email address, notifying the user about the potential gas leakage. The email contains detailed information, including the current gas level, timestamp, and status of other system parameters, allowing the user to assess the severity of the situation quickly. In addition to email notifications, the system automatically turns on the exhaust fan to dissipate the leaked gas and mitigate the risk of fire or explosion. Simultaneously, the real-time data displayed on the Blynk dashboard helps users monitor gas levels and system status remotely, providing a proactive approach to gas leakage management. The integration of these features ensures a comprehensive response to potential gas leakage incidents and enhances overall safety. Fig. 4.1 below shows the full setup with the MQ6 sensor.

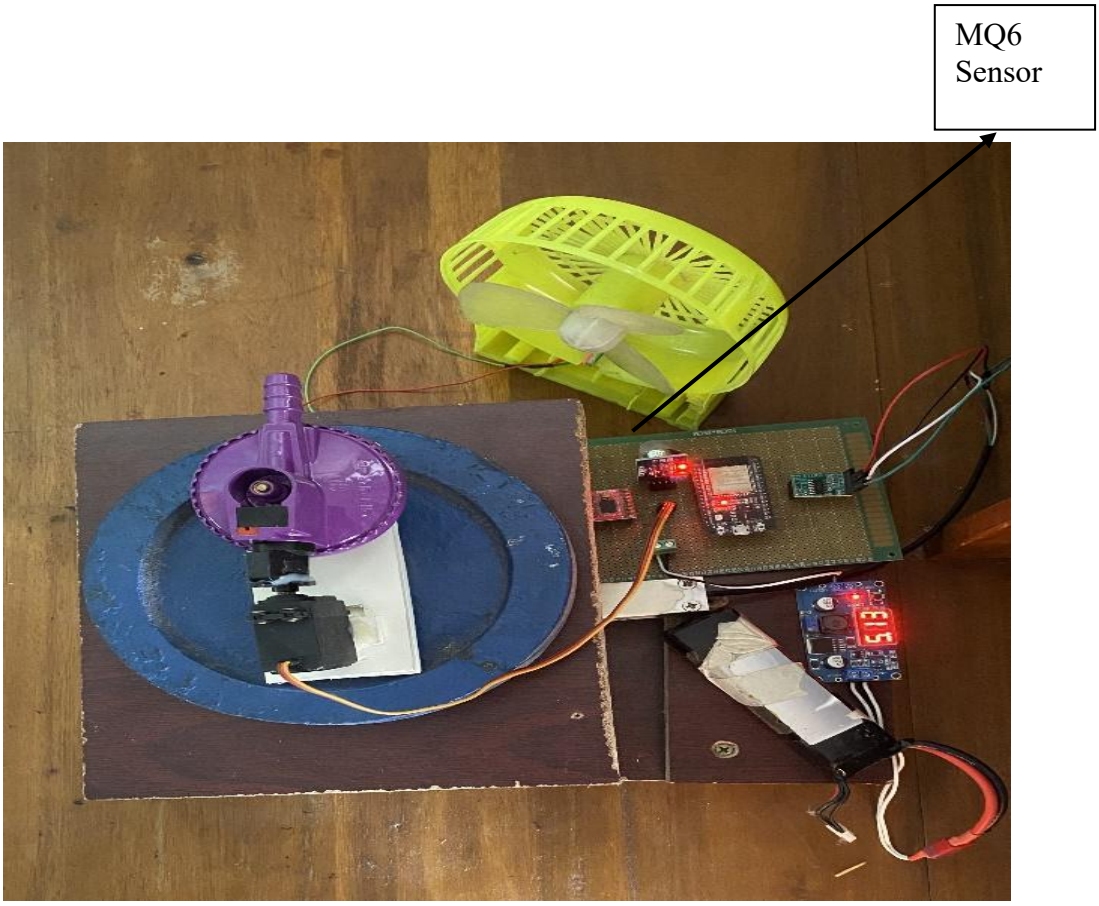


Fig. 4.1: Arrangement of gas leakage detection system

The successful implementation of this smart gas leakage detection and monitoring system demonstrates its reliability and effectiveness in real-world scenarios. The accuracy of the MQ6 sensor, combined with the automated response mechanisms and IoT-enabled remote monitoring, positions this system as a robust solution for detecting, monitoring, and preventing gas leakages in residential and industrial settings. This multi-layered approach ensures both early detection and timely intervention, ultimately safeguarding users from potential hazards. In the Fig. 4.2 and 4.3 the normal state Graphical User Interface of the Blynk app is illustrated.

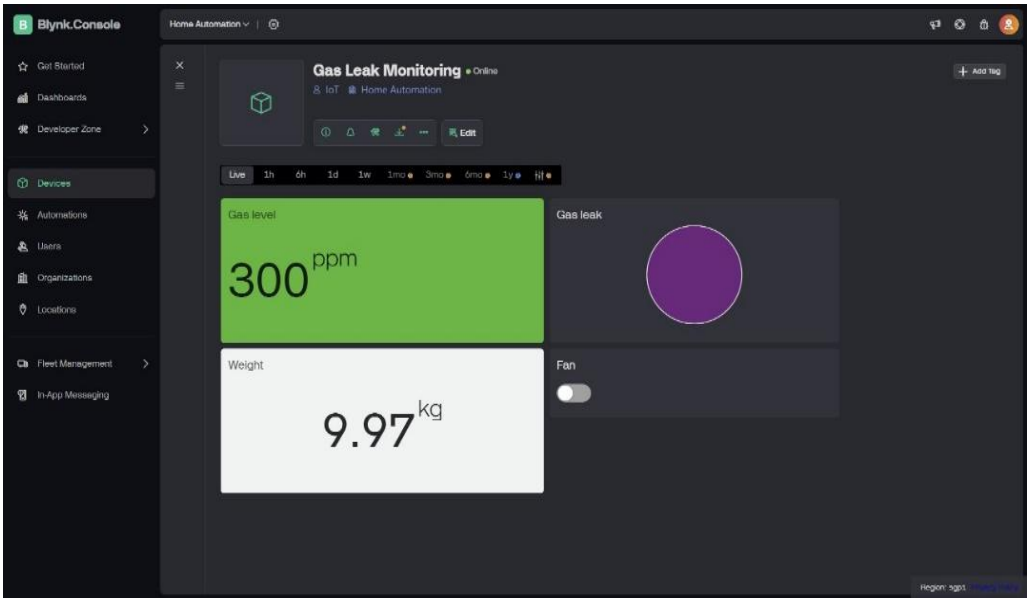


Fig.4.2: Implemented Blynk Dashboard (Website)



Fig.4.3: Implemented Blynk Dashboard (Mobile)

This comprehensive data provides the user with a clear understanding of the situation's severity and helps them make informed decisions quickly. Additionally, the email notification is designed to be highly descriptive and user-friendly, ensuring that critical information is highlighted for immediate attention. By including real-time gas concentration levels and system statuses, the notification eliminates ambiguity and allows

users to take prompt actions, such as shutting off the gas supply, activating additional safety measures, or alerting emergency services if necessary.

The timely delivery of this detailed alert significantly enhances safety by facilitating quick and appropriate responses to gas leakage incidents. The inclusion of the timestamp ensures that the exact time of the incident is logged for further analysis or reporting. Additionally, the system provides information about the operational status of other components, such as the exhaust fan and cylinder weight, offering a comprehensive overview of the current scenario. By receiving this detailed notification, the user can take immediate and appropriate action, such as shutting off the gas supply, activating further safety measures, or notifying emergency services if necessary.

This prompt and information-rich alert system plays a crucial role in minimizing risks associated with gas leakage incidents, as it ensures that the user remains fully informed and equipped to respond to the emergency effectively. Fig 4.4 shows the real time email alert.

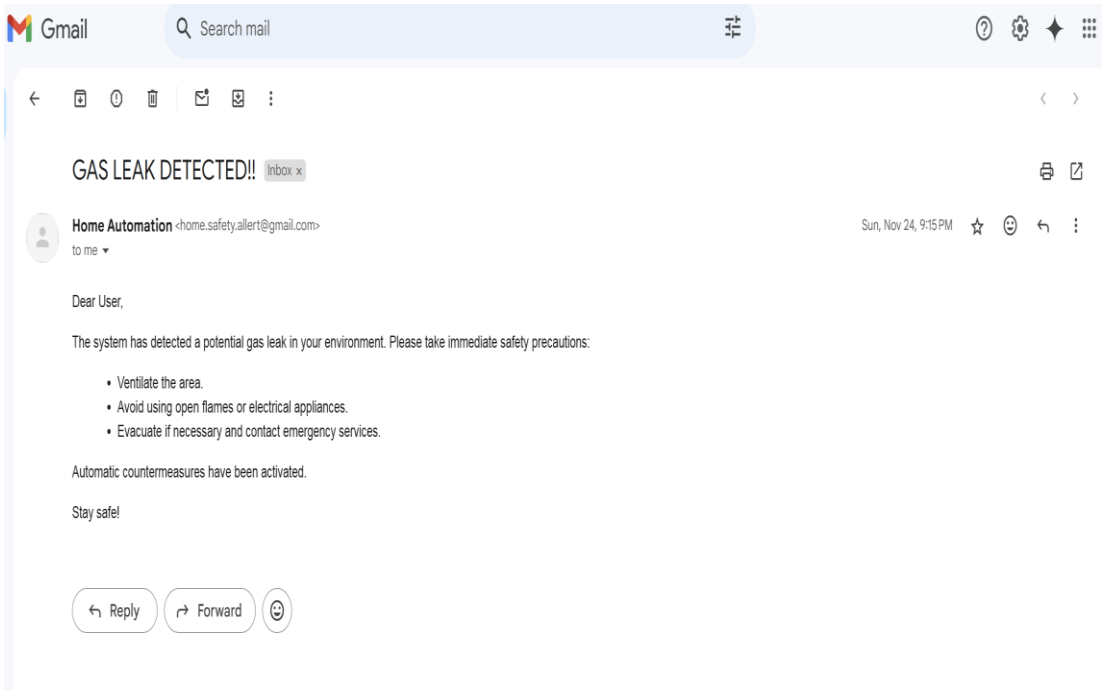


Fig.4.4: Email alert notification

Without a delay, the exhaust fans are turned on the reduce the gas concentration from the area. According to tests conducted in an enclosed space, there was an average 30% drop in gas level within the first 5 minutes of activation. Gas dissipation rate depends on exhaust fan size. The use of an H-bridge driver allowed us to control the exhaust fan speed according to the gas level. Thus, making the system more energy efficient. Figure 4.5 shows the gas dissipation over time obtained from one of the many test runs.

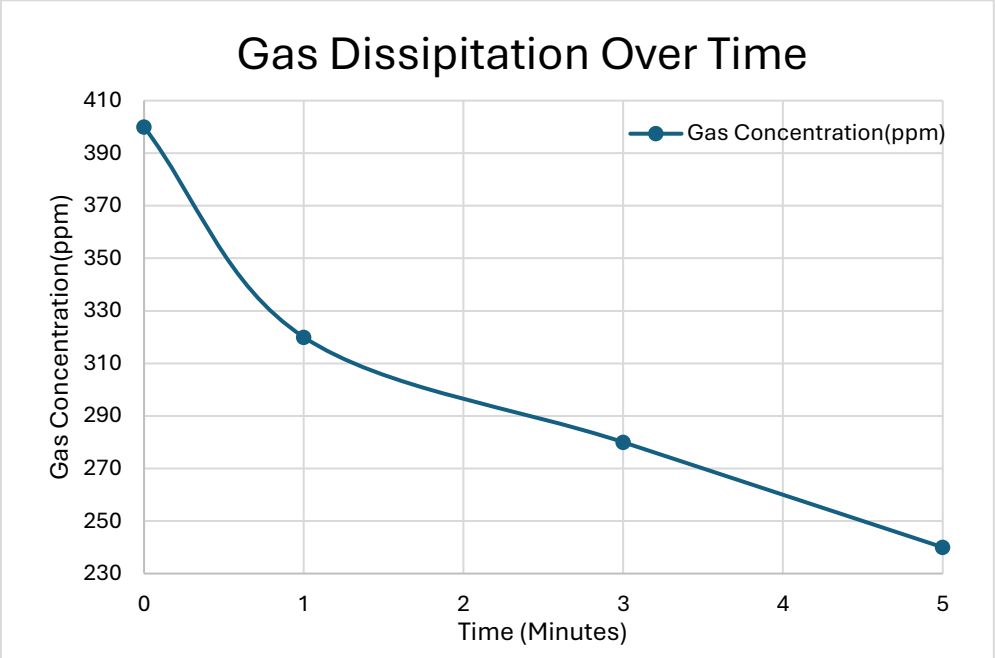


Fig.4.5: Gas dissipation over time

The servo motor that controls the gas valve showed reliable performance in shutting down the gas supply when gas levels reached a critical point. The actuation delay for closing the valve was measured to be 1.5-1.8 seconds after reaching the threshold. The high torque of the servo motor made it possible to open and close the valve with ease. The weight of the gas cylinder is measured by the load cell and transmitted the data to the Blynk server. Tests with conventional weight scales showed a margin of error of within 1.5%. The error can be adjusted with further modification of the calibration factor.

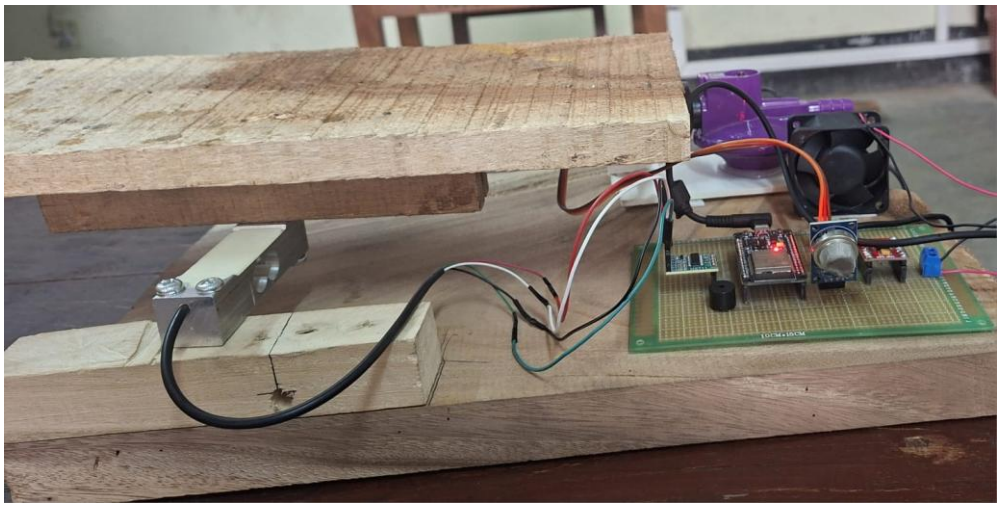


Fig. 4.6: Overall Integrated System

All of the components worked seamlessly in an integrated setup. Blynk interface provided users with real-time data visualization and control options. The system's ability to send alerts and control actuating components autonomously is highly effective. The simulation is also carried out using proteus software and Fig 4.7 illustrates the simulation interface.

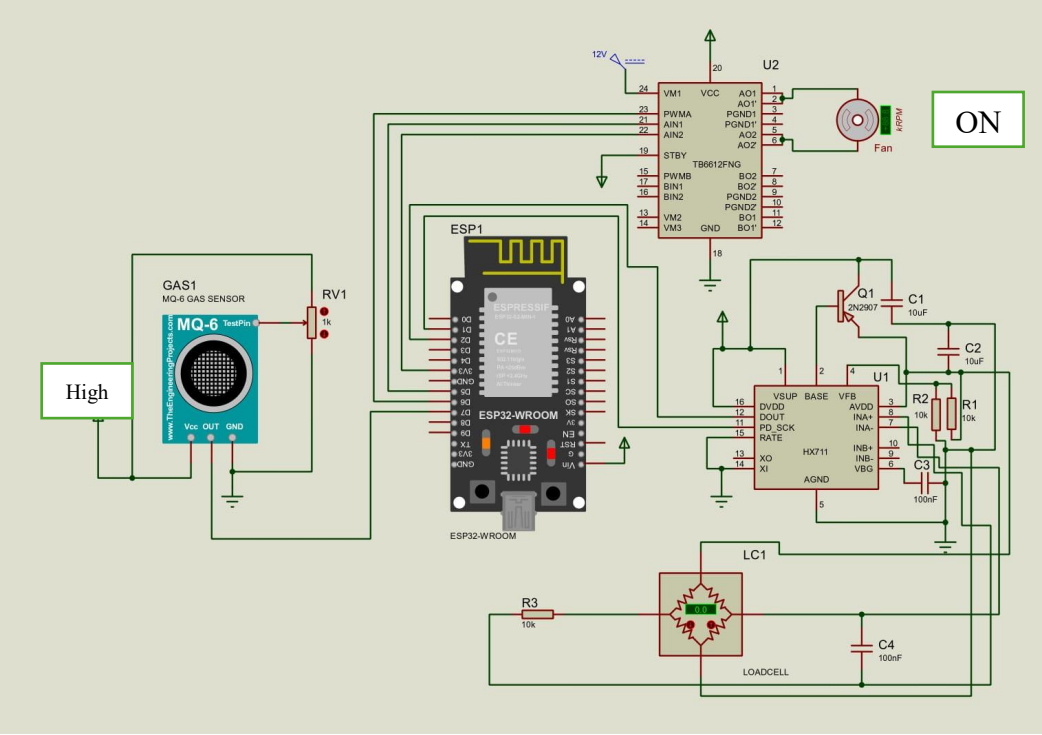


Fig. 4.7: Simulation of the whole system in proteus

4.3 Implementation of LPG cylinder weight monitoring system and overall integrated system

The weight of gas cylinder will be measured in a load cell. The 50kg load cell is selected since the entire weight of LPG gas cylinder containing gas is 24.2kg and that of an empty one is about 12.2kg. Each of the tanks is standard with 12kg of gas fill up. To start with, a process of calibration takes place. This is necessary so as to allow the load cell to read the right reading. To get the weight of the gas cylinder LPG, there is an electronic weighing scale which is used as reference. This is to ensure that, the load cell reading, once calibrated, corresponds with the reading of the reference weighing scale. In several trial runs, the value of calibration factor will be 0.03451. In fig. 4.1 the load cell is attached to the NODEMCU ESP 8266 and a weight is put on top of the load cell. Load cell is coupled with the HX711 amplifier and amplifier is coupled with NODEMCU ESP8266. Signals

of a load cell are analog in nature. fig. 4.2 depicts load cell reading which is consistent with reference in fig.9. Therefore, the calibration factor has been fixed for the entire project. The following table 4.1shows the actual weight and measured weight of the loadcell.

Table 4.1: Measured weight vs actual weight

Trail No	Actual Weight(in kg)	Measured Weight(By Loadcell in Kg)
1	12	11.78
2	10	9.81
3	05	1.91
4	02	1.91
5	01	1
6	08	7.82
7	15	14.52
8	24.2	24.04
9	12	11.80
10	20	19.60
11	7.5	7.35
12	5.2	5.1

Now after doing some calculation it is found that-

Table 4.2: Mathematical Calculation

Trial	**Actual (kg)**	**Measured (kg)**	**Error**	**Absolute Error**	**Squared Error**	**APE (%)**
1	12.00	11.78	-0.22	0.22	0.0484	1.83
2	10.00	9.81	-0.19	0.19	0.0361	1.90
3	5.00	1.91	-3.09	3.09	9.5481	61.80
4	2.00	1.91	-0.09	0.09	0.0081	4.50
5	1.00	1.00	0.00	0.00	0.0000	0.00
6	8.00	7.82	-0.18	0.18	0.0324	2.25
7	15.00	14.52	-0.48	0.48	0.2304	3.20
8	24.20	24.04	-0.16	0.16	0.0256	0.66
9	12.00	11.80	-0.20	0.20	0.0400	1.67

10	20.00	19.60	-0.40	0.40	0.1600	2.00
11	7.50	7.35	-0.15	0.15	0.0225	2.00
12	5.20	5.10	-0.10	0.10	0.0100	1.92

Now we know these formulas-

Mean absolute error (MAE)= $\frac{1}{n}\sum_{i=1}^{n}|y_i - \overrightarrow{y_i}|$ .....equ (4.1)

Mean Squared error (MSE)= $\frac{1}{n}\sum_{i=1}^{n}(y_i - \overrightarrow{y_i})^2$.....equ (4.2)

Root Mean Squared error (RMSE)= √MSE

Mean Absolute Percentage Error (MAPE)= $\frac{100\%}{n}\sum_{i=1}^{n}\left|\frac{y_i - \overrightarrow{y_i}}{y_i}\right|$... equ (4.3)

Accuracy= 100% −MAPE

After calculating the final value comes as presented in table 4.3-

Table 4.3: Load cell Performance Matrix

Metric	Value
MAE (kg)	0.4383
MSE (kg²)	0.8468
RMSE (kg)	0.9202
MAPE (%)	6.9779%
Accuracy (%)	93.0221%
R^2 Score	0.9811

4.3.1 Uncertainty Analysis:

Organize the data with error

Table 4.4 Uncertainty Analysis

Trial	**Actual Weight (kg)**	**Measured Weight (kg)**	**Error = (Measured - Actual) (kg)**
1	12.00	11.78	-0.22
2	10.00	9.81	-0.19
3	5.00	1.91	-3.09

4	2.00	1.91	-0.09
5	1.00	1.00	0.00
6	8.00	7.82	-0.18
7	15.00	14.52	-0.48
8	24.20	24.04	-0.16
9	12.00	11.80	-0.20
10	20.00	19.60	-0.40
11	7.50	7.35	-0.15
12	5.20	5.10	-0.10

Basic Statistics

- Mean Error (Bias):

  $\bar{E} = \sum \frac{error}{n} = -\frac{5.26}{12} =$ -0.44 kg…….equ (4.4)

- Standard Deviation of Error (σ):

  $\sigma = \sqrt{\frac{\sum (E_i - \bar{E})^2}{n-1}} \approx 0.84$kg ……equ (4.5)

Expanded Uncertainty (with 95% confidence level)

Using the coverage factor **k = 2** (common for 95% confidence):

U = k·σ= 2·0.84 = ± 1.68 kg ……equ.(4.6)

So, each measurement should be reported with **± 1.68 kg uncertainty** unless better calibration or equipment is used.

4.5 Cost Analysis

As this is a low-cost solution of the gas leakage and prevention system cost analysis is very important. Table 4.4 below illustrates the cost analysis-

Table 4.5: Illustration of costing.

Name of the component	Description	Approximate Price in BDT
ESP8266 IoT module	The microcontroller of the whole project	1500.00
Load Sensor	To detect the weight of the gas cylinder (50Kg limit)	4500.00
HX711 Load cell Amplifier	To amplify the load cell signal	500.00
Shut Off valve	To shut down the gas flow	500.00
Fan	To reduce the gas leakage flow in the environment (primary step)	400.00
Servo Motor	To turn the knob of shutoff valve	1500.00
MQ6 gas sensor	This sensor detects the presence of gas in the environment	1000.00
Buck converter	To give regulated power supply	200.00
	Total (tk) =	10,100.00

So, without mechanical auto shut off device and the Li-po battery the costing is around 10,000 Tk which is a very cost-effective system.

4.5 Comparison Between Marketed Auto Shut Off Device Vs Proposed System

Fig. 4.8 below is the marketed/existing Gas Safety Device/Regulator.



Fig. 4. 8: Marketed auto shut-off device

This device automatically shut-off the gas supply from the cylinder only **major leakages (above 50,000 PPM)** of gas caused due to.

1. The rupturing of a tube or pulling off the stove or regulator.
2. The regulator failing to function properly.
3. The supply pipe catching fire.

A marketed auto shutoff device that activates above 50,000 ppm (5%) is extremely dangerous, especially for natural gas (methane) and LPG (propane/butane) because:

50,000 ppm is vulnerable:

- Natural gas (Methane, CH_4): LEL is 5% (50,000 ppm) → At this level, the gas is already at its explosive threshold!
- LPG (Propane, C_3H_8 & Butane, C_4H_{10}): LEL is 2.1% (21,000 ppm) for propane and 1.6% (16,000 ppm) for butane → 50,000 ppm is far above their explosive limits.

Associated high risk at marketed auto shut off device :

1. High Explosion Risk – The shutoff activates only when the gas is already in an explosive range.
2. Too Late to Prevent Disaster – Gas leaks should be stopped at much lower concentrations to prevent accumulation.

   A device that waits until 50,000 ppm (5%) to shut off gas is dangerously late and not a good safety measure.

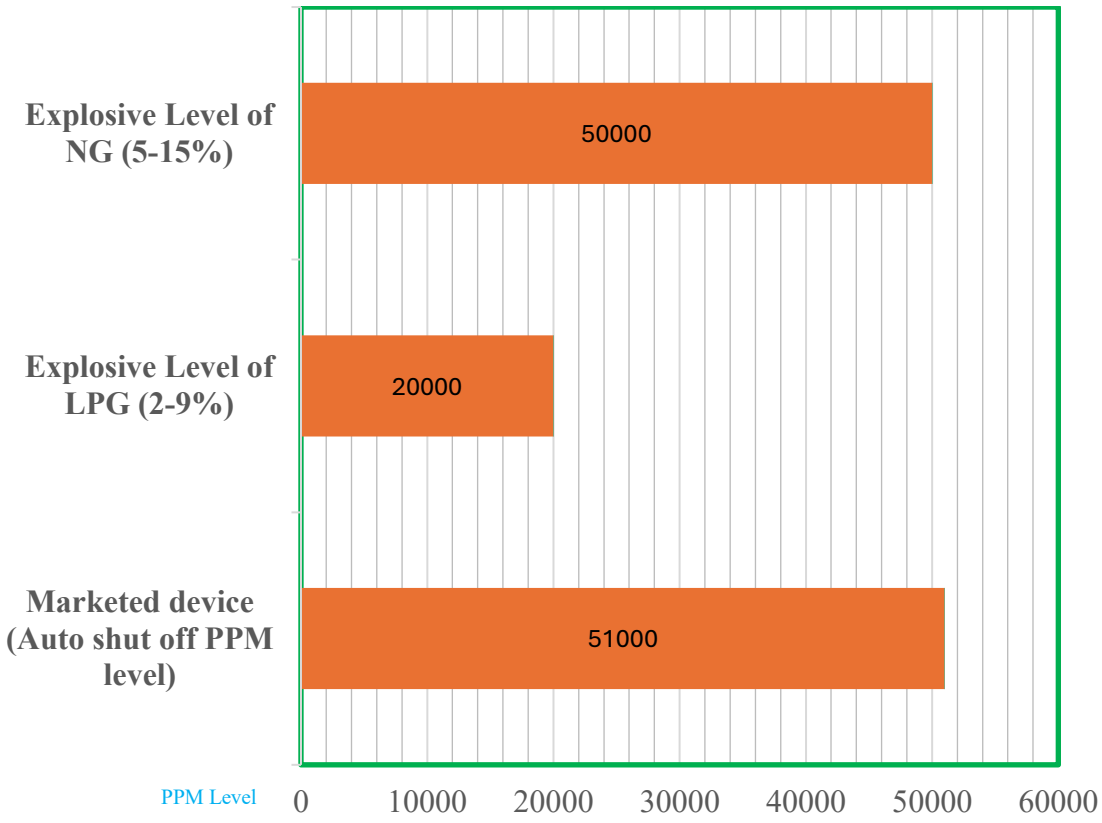


Fig. 4. 9: Auto Shut-off PPM level of marketed Auto shut off device

From this fig. 4.9 we see that marketed auto shut off device is dangerous for home, it will work gas leakage when reached at above 50000 PPM (5% by volume) which more enough to occurring a fire explosion. Lowest explosive level of LPG 20,000 PPM(2% by Volume). If only we used this device gas leakage can not stopped, and fire explosion can happen. From minor leakage , gas is associated on floor and occur an fire accident.

proposed IoT based system give notification when leakage of gas level 200 PPM (0.02%) exhaust fan is on and take auto action to close the cylinder knob further gas leakage will stop. As a result gas will not associated on floor and home is secure from fire accident.

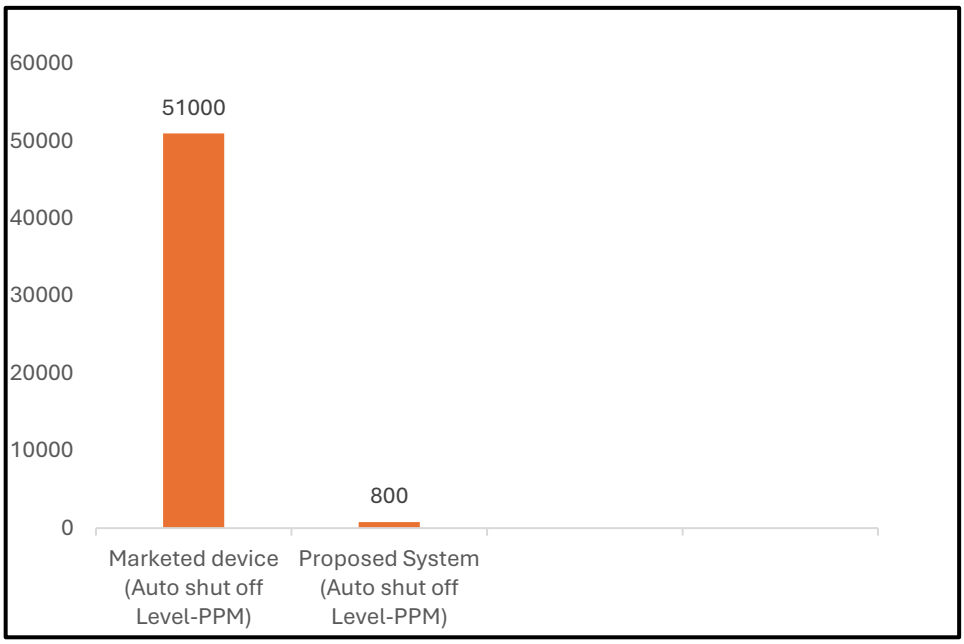


Fig. 4.10: Comparison of Auto shut off level between Proposed system vs Marketed device.

Table 4.6: Comparison data table.

Feature	Marketed Device	Proposed System
Leak Detection	No	Yes
Auto Shut-Off	Yes (above UEL)	Yes (below LEL)
Alert to User (SMS/App)	No	Yes
Multistage Prevention	No	Yes
Gas Level Monitoring	No	Yes
Emergency Power Cut-Off	No	Yes

4.6 Discussion

The need to have a smart gas leakage detection and prevention system has been on the rise attributed to increased concern on fire hazards, explosions and poisoning associated with leakage of gases in domestic, industrial and commercial settings. Implementation of IoT (Internet of Things) into them allows them to become more efficient and reliable, increasing the real-time monitoring, remote control, and automated prevention measures.

The smart gas leakage detection and prevention system that have been proposed was defined to mitigate the safety issues related to the application of the liquefied petroleum gas (LPG) and piped natural gas in residential and commercial premises. The system is successful in meeting its major purpose of automatically cutting off the flow of gas in LPG cylinder when the concentration of the gas and air mixture in the cylinder exceeds a predetermined percentage of concentration and thus reduces the chances of explosion or fire. This is done by interfacing gas sensors with a servo controlled valve which will react to the presence of hazardous gas by chopping the gas supply. This is comparatively quicker and more sure response to the hazardous leak situations, than in conventional manual/semi-automatic regulators. In addition to automatic shut-off, the system enhances safety by alerting users via an IoT-based Android application when gas leakage is detected or when the LPG cylinder level becomes critically low. The system also activates an exhaust fan to ventilate the area and a buzzer to warn nearby individuals, ensuring a multilayered response to potential threats. These features are particularly beneficial in households where immediate human intervention may not be possible, such as in the absence of occupants or during sleep.

Furthermore, this research explores the underlying causes of gas leaks in piped natural gas systems, such as corrosion, joint failures, faulty appliances, or pressure fluctuations. Based on this analysis, the system offers a foundation for developing preventive strategies including regular inspection protocols, real-time leak monitoring, and smart notification systems integrated with emergency services. Lastly, the performance and reliability of the proposed IoT-based system were compared with existing commercial auto shut-off devices available for LPG cylinders. The results indicate that while traditional shut-off regulators can react to sudden pressure drops or hose failures, they lack the capability to monitor gas concentration levels, send real-time alerts, or coordinate automated electrical and ventilation controls. In contrast, the proposed system offers a comprehensive safety

solution with approximately 98% accuracy in detection and shut-off performance, demonstrating significant improvement in responsiveness, user communication, and overall reliability. Overall, the proposed system not only bridges technological and functional gaps found in current market solutions but also presents a cost-effective, scalable model that can be adopted widely to improve gas safety in both residential and commercial environments.

Advantages of IoT-Based Smart Gas Detection

By integrating gas sensors (MQ-6), IoT platforms, mobile apps, and automation mechanisms, the system offers:

- 24/7 real-time monitoring via cloud and mobile apps.
- Instant alerts via SMS, emails, or app notifications.
- Automatic shutdown of gas supply via a servo motor.
- Activation of exhaust fans to disperse leaked gas.
- Data logging and analytics to predict potential leaks.

Unlike basic gas alarms, a multistage approach enhances safety by responding progressively:

Table 4.7: Multistage Prevention approach

PPP Level	Buzzer	Exhaust Fan	GSM module	Blynk dash board mobile	Shut off electric Power using realy	Servo motor activate	Auto shut off valve
≤=299 ppm	off	off		No message	no response	no response	no response
≥ = 300 ppm	on	on		gas leakage detected	no response	no response	no response
≥ = 800 pmm	on	on	Emerge-ncy alert sms sent	gas leakage detected	auto shut off electric power	close the lpg cylinder knob	no response

<= 50,000ppm (due to rupture/tear /brusting of hose pipe)							shut of gas supply from lpg cylinder with in a second

•Stage 1 - Early Detection and Warning, Sensor detects low gas concentration, Notification sent to the user via IoT,

•Stage 2 – Active Warning and Fan Activation, Buzzer sounds an alert; Exhaust fan turns ON to reduce gas buildup.

•Stage 3 – Automatic Gas Shutdown: Gas concentration crosses safe limits, motor closes the gas supply. Emergency alert sent to homeowner/industry supervisor.

•Stage 4 – Emergency Response:If leak persists, emergency contacts (fire department, gas company) are alerted. Data logs help in further investigation.

Implementation Considerations

Reliability of Sensors: Gas sensors have calibrated to reduce false alarms.

Internet Connectivity: Used GSM in areas without Wi-Fi access.

Power Backup: we have used extra power source (Lipo battery).

Future Enhancements

AI-Based Predictive Maintenance: Predict leaks before they occur using data analytics.

Integration with Smart Home Systems: Connect to Alexa, Google Home for voice control.

GPS Tracking for Mobile Gas Tankers: Monitor leaks in moving vehicles. Although this study has achieved significant milestones, there are several areas that warrant further exploration and improvement:

Enhanced Sensor Accuracy: Investigating advanced gas sensors with higher sensitivity and selectivity could improve detection accuracy for a wider range of gases.

Integration of AI and Machine Learning: Implementing AI-based predictive analytics could enable the system to forecast potential leakage scenarios and optimize the multistage response.

Energy Optimization: Exploring renewable energy sources, such as solar panels, to power the system can make it more sustainable for long-term usage.

Scalability for Industrial Use: Adapting the system for large-scale industrial settings by incorporating additional features, such as multiple gas detection and advanced alert mechanisms.

Customization and User Accessibility: Developing multilingual and user-friendly interfaces to cater to diverse users, including those with limited technical expertise.

Safety Standards and Certifications: Enhancing compliance with global safety standards to ensure that the system can be widely adopted in residential and commercial applications.

4.7 Conclusion

An IoT-based gas leakage detection and prevention system enhances safety by providing real-time monitoring, instant alerts, and automated countermeasures. With the advancement of smart home technologies, integrating AI, cloud storage, and mobile apps now very effective and reliable.

Chapter 05

Conclusion and Recommendations

5.1 Introduction

This chapter summarizes the findings of the study, highlights the key contributions and provides final remarks on the developed system's effectiveness. The goal is to reflect on the implications of the study while identifying areas for improvement and further exploration. Also explain safety recommendations for using LPG cylinder to minimize risks such as leaks, explosions or fires. The proposed smart gas leakage detection, monitoring, and multistage prevention system offers a comprehensive and intelligent solution to one of the most pressing safety concerns in households and commercial facilities that rely on LPG and piped natural gas. By integrating advanced sensors, IoT-based alert systems, automated shut-off mechanisms, and real-time gas level monitoring, this system significantly enhances early leak detection and rapid emergency response. Unlike conventional auto shut-off devices, it not only reacts to dangerous situations but also prevents them from escalating by controlling multiple parameters simultaneously gas flow, ventilation, electrical power, and user notification. The ability to analyze leakage causes in piped gas networks and develop targeted preventive strategies further adds value to this innovation. With an estimated 98% reliability in emergency shut-off operation, the system ensures greater safety, peace of mind, and protection of life and property. As gas usage continues to grow, adopting such smart, efficient, and cost-effective safety technologies is not just an option it is a necessity for a safer, smarter future.

5.2 Summary of findings

The primary objective of this research was to design and develop a smart gas leakage detection, monitoring, and multistage prevention system using IoT technologies. Based on the extensive testing and analysis performed, the following key findings have been established:

- Accurate Detection: The MQ6 sensor demonstrated high reliability and accuracy in detecting gas concentrations under varying environmental conditions.

The system successfully identified even small fluctuations in gas levels, triggering timely alerts to mitigate potential hazards.

• Multistage Response System**:** The system effectively implemented a multi-layered protection mechanism. This included sending real-time email alerts, activating exhaust fans, and shutting off the gas supply via a servo motor.

The email notification was highly informative, providing critical details such as gas concentration, system status, and timestamp, ensuring user preparedness.

• Real-Time Monitoring: Integration with the Blynk IoT platform allowed seamless real-time data transmission, visualization, and control via both mobile and web dashboards.The data collection from sensors like the load cell, gas sensor, and system status components ensured comprehensive monitoring.

• Efficiency of Actuating Components**:** The servo motor showed minimal delay in shutting off the gas supply, ensuring immediate action during critical situations.

The exhaust fan, controlled by an H-bridge driver, reduced gas concentration by an average of 30% within the first five minutes, showcasing its efficiency in dissipating leaked gas.

• Integrated System Performance**:**The fully integrated system demonstrated a robust ability to detect, monitor, and prevent gas leakage incidents autonomously.

The system maintained an overall error margin of less than 1.5% in weight measurement, indicating its precision.

5.3 Summary:

The smart gas leakage detection, monitoring, and multistage prevention system developed in this study is a cost-effective and efficient solution for addressing the risks associated with gas leakage. The combination of IoT-enabled real-time monitoring, multi-layered response mechanisms, and user-friendly interfaces ensures that the system not only detects gas leakage but also takes immediate and effective preventive actions.The study highlights the potential of IoT technologies in enhancing safety and sustainability in residential and industrial settings. By enabling early detection and automated responses, the system mitigates risks, minimizes property damage, and protects human lives. While the results are promising, further refinement and innovation in the system's design could broaden its applicability and impact. Future advancements, such as AI integration and industrial scalability, can transform this system into a universal solution for gas safety management. In conclusion, this research contributes to the growing field of IoT-based safety systems, demonstrating how smart technologies can be leveraged to enhance everyday life. The

findings pave the way for continued innovation and adoption of similar systems in ensuring a safer and smarter world.

5.4 Recommendations:

To overcome the existing and upcoming challenges of gas leakage hazardous is the demand of time. Here are safety recommendations for using LPG cylinders to minimize risks such as leaks, explosions or fires:

I. Storage and Handling **:** Keep LPG cylinders in a well-ventilated open space to prevent gas accumulation in case of a leak. Avoid storing in basements or enclosed areas. Store cylinders away from direct sunlight, open flames, or heat-emitting appliances. Auto-ignition temperature of LPG is typically around 410°C to 580°C (770°F to 1076°F, LPG will ignite without any external flame or spark. Never utilize matches or lighters to check for leaks.

II. Use only certified and approved LPG cylinders. Do not use damaged or expired cylinders. And checked the expiry date of LPG cylinder.

III. Such logistics like BRTA paying greater care in free movement of LPG carriers and making them as emergency item can elevate the industrial advancement. The whole of the value chain that involves LPG cylinder/Bottle importation, storage, bottling, transportation, marketing and use has to be safe enough.

IV. The presently existing private LPG cylinder companies should also take the gradual step of concentrating on the safety at the end user level, and the safety of the cylinder is of utmost importance. The cylinders should be retested every 05 years of use and the government ought to stop illegal refilling since there have been a few accidents already. Which would be of assistance in creating safe environment between the sellers and the consumers.

V. The Explosives Department if doing their job properly, go to every area in the country and showing how to use LPG cylinders, providing basic knowledge of proper use of LPG cylinder and removal to dispose of accident. if the consumers do not accept LPG rule legal action should be taken against them in this regard. After a certain period the explosives inspectorate will check LPG cylinder and give the fitness certificate then everyone is aware of this and the level of risk will be reduced. By following these safety measures can significantly reduce the risks associated with using LPG cylinders.

References

[1] M. A. Islam, S. C. Banik, K. A. Rahman, and M. T. Islam, "A review study of the safety issue for workers of LPG bottling plant due to radiation from LPG," in *Proc. Int. Conf. Mech. Eng. Renew. Energy (ICMERE)*, 2021, pp. 12–14.

[2] M. Momtaz, N. Tasnim, and M. A. A. S. Choudhury, "A review of liquefied petroleum gas (LPG) as an alternative fuel option and its market scenario in Bangladesh," in *Proc. Int. Conf. Petroleum Eng. (ICPE)*, 2019.

[3] M. S. Hossain, *The Fundamental of Fossil Fuels and Pricing Methodology*, 2022.

[4] Oil and Gas Info, "Fractional distillation," [Online]. Available: https://oilandgasinfo.ca/patchworks/fractional-distillation

[5] G. Bartnik, K. Plizga, D. Dziki, Z. Kaliniewicz, A. Nieoczym, A. Wyciszkiewicz, and T. Otto, "Analysis of tank safety with propane-butane on LPG distribution station," *Pol. J. Chem. Technol.*, vol. 19, no. 4, pp. 99–102, 2017, doi: 10.1515/pjct-2017-0074.

[6] M. A. Rahman, M. A. Islam, and A. K. M. N. Islam, "Popularizing liquefied petroleum gas (LPG) as an alternative to piped natural gas for domestic use: Bangladesh perspective," *J. Chem. Eng., IEB*, vol. 30, no. 1, pp. 16–20, 2017.

[7] "Fire burns down gas cylinder shop in Sylhet," *bdnews24.com*, Mar. 1, 2022. [Online]. Available: https://bdnews24.com/bangladesh/fire-burns-down-gas-cylinder-shop-in-sylhet

[8] P. K. Pateriya, A. A. Munna, A. Saha, H. Biswas, A. Ahammed, and A. Shah, "IoT-based LPG gas leakage detection and prevention system," in *Proc. Int. Conf. Intell. Comput. Control Syst. (ICICC)*, 2021.

[9] M. H. B. M. Yaya, R. K. Patchmuthu, and A. T. Wan, "LPG gas usage and leakage detection using IoT in Brunei," in *Proc. Int. Conf. Green Energy, Comput. Sustain. Technol. (GECOST)*, 2021, pp. 1–5.

[10] J. Ahmed, J. Rahman, and M. A. Razzak, "Design and development of an IoT-based LPG gas leakage detector for households and industries," in *Proc. IEEE World AI IoT Congr. (AIIoT)*, 2023, pp. 762–767.

[11] K. S. Chakradhar, R. Deshmukh, P. P. Singh, B. Hazela, and R. Taluja, "LPG cylinder leakage monitoring by IoT," in *Proc. Int. Conf. Inventive Comput. Technol. (ICICT)*, 2023, pp. 1386–1389.

[12] V. S. D. Rekha, N. S. M. CH, and A. Sravya, "Condition monitoring and detection of hazardous gas leakage using smart device," in *Proc. Int. Conf. Electron. Renew. Syst. (ICEARS)*, 2022, pp. 396–400.

[13] V. P. Sharma, D. Raman, V. Padmavathi, and G. V. R. Gurram, "IoT based gas leakage detection system using GPS," *E3S Web Conf.*, vol. 391, p. 01064, 2023.

[14] P. Naveen, K. R. Teja, K. S. Reddy, S. M. Sam, M. D. Kumar, and M. Saravanan, "ATMEGA 328-based gas leakage monitoring and alerting IoT system with SMS notification," in *Proc. Int. Conf. Adv. Comput. Commun. Syst. (ICACCS)*, vol. 1, 2023, pp. 1300–1305.

[15] C. Sandhra and R. Manjunatha, "IoT-enabled smart benzene gas detection system in petrol pumps for smart city applications," in *Proc. Int. Conf. Emerg. Tech. Comput. Intell. (ICETCI)*, 2023, pp. 145–152.

[16] A. A. Mim, N. Akter, M. N. Hasan, J. F. Shoma, and A. Sattar, "Gas leakage with auto ventilation and smart management system using IoT," in *Proc. Int. Conf. Artif. Intell. Smart Syst. (ICAIS)*, 2021, pp. 1411–1415.

[17] S. S. Michael, J. A. Jenifer, R. M. Benjamin, C. Jacob, and S. Shanthosh, "Smart security management using IoT and HC-05 Bluetooth module," in *Proc. Int. Conf. Inventive Syst. Control (ICISC)*, 2024, pp. 550–554.

[18] J. Praveenchandar *et al.*, "IoT-based harmful toxic gases monitoring and fault detection on the sensor dataset using deep learning techniques," *Sci. Program.*, vol. 2022, Article ID 7516328, 2022.

[19] M. Uzair, S. Y. Al-Kafrawi, K. M. Al-Janadi, and I. A. Al-Bulushi, "A low-cost IoT based buildings management system (BMS) using Arduino Mega 2560 and Raspberry Pi 4 for smart monitoring and automation," *Int. J. Electr. Comput. Eng. Syst.*, vol. 13, no. 3, pp. 219–236, 2022.

[20] D. M. Shelke *et al.*, "Smart MQ6 gas detector based on IoT," in *Proc. Int. Conf. I-SMAC (IoT in Social, Mobile, Analytics and Cloud)*, 2023, pp. 1–6.

[21] Chattopadhyay, "Smart home automation system using Raspberry Pi and Google Cloud," in *Proc. Int. Symp. IoT Solutions*, 2021.

[22] A. Balaji, B. Sathyasri, D. Indumathy, R. Krishnan, and S. Vanaja, "Intruder alert system in smart home based on IoT technique," in *Proc. Int. Conf. Power, Energy, Control and Transmission Syst. (ICPECTS)*, 2022, pp. 1–4.

[23] A. Manhas, N. Chambyal, M. Raina, S. Dutta, and P. Singh, "LPG gas leakage detection using IoT," *Int. J. Sci. Res. Sci. Technol.*, vol. 8, no. 1, pp. 520–526, 2021.

[24] R. Islam, M. I. Hossain, M. S. Rahman, S. Kabir, M. S. R. Sohan, and A. Shufian, "Smart IoT system for automatic detection and protection from indoor hazards: An experimental study," in *Proc. IEEE Region 10 Humanitarian Technol. Conf. (R10-HTC)*, 2022, pp. 112–117.

[25] Suhartono and I. Suhardi, "Pressure measurement algorithm of LPG leakage using MQ6 sensor and GSM SIM900 for smart home," *ILKOM J. Ilmiah*, vol. 13, no. 2, pp. 78–85, 2021.

[26] A. Chandak, A. Kolhe, S. Shirke, S. Kurumbanshi, and S. Patil, "IoT based LPG cylinder monitoring system," *Int. J. Innov. Res. Electron. Commun.*, vol. 7, no. 2, pp. 1–7, 2020.

[27] A. Agarwal, A. Dwivedi, V. Jain, and P. Yadav, "Safety kit for domestic LPG," *Int. J. Innov. Res. Electr., Electron., Instrum. Control Eng.*, vol. 7, no. 5, May 2019.

[28] B. Shilpa and R. Jayasudha, "LPG gas measurement & detection using GPS," *Int. J. Innov. Technol. Explor. Eng. (IJITEE)*, vol. 8, no. 9, July 2019.

[29] C. Ramesh, S. R. Mahesh, R. Pooja, P. K. Mane, and S. Kumuda, "LPG detection, measurement and booking system," *Int. J. Res. Sci. Innov. (IJRSI)*, vol. 1, no. 6, Nov. 2014.

[30] S. Anandhakrishnan, D. Nair, R. K., K. Sampath, and S. N. Gayathri, "IoT based smart gas monitoring system," *IOSR J. Electr. Electron. Eng. (IOSR-JEEE)*.

[31] K. Priya and K. Kowsalya, "Detecting LPG leakage and automatic turn off using Arduino connected with PIR sensor," in *Proc. Recent Adv. Smart Comput. Commun. (RASCC)*, 2020.

[32] J. Leavline, D. A. A. G. Singh, and B. Abinaya, "LPG gas leakage detection and alert system," *Int. J. Electron. Eng. Res.*, vol. 9, no. 7, pp. 1095–1097, 2017.

[33] N. Wickramasinghe and N. Nabhayasinghe, "LPGAS leakage alarm," Apr. 2013.

[34] P. S. Jadhwani, S. R. Patil, T. S. Shinde, and S. Patil, "LPG gas leakage detection and alert system using Arduino," *Int. J. Res. Appl. Sci. Eng. Technol. (IJRASET)*, vol. 9, no. 5, May 2021.

[35] J. Soundarya and V. Anchitaalagammai, "Control and monitoring system for liquefied petroleum gas (LPG) detection and prevention," *Int. J. Innov. Res. Sci., Eng. Technol.*, vol. 3, Special Issue 3, Mar. 2014.

[36] A. Amsaveni, R. S. Anurupa, C. Malarvizhi, and M. Gunasekaran, "GSM based LPG leakage detection and controlling system," *Int. J. Eng. Sci. (IJES)*, pp. 112–116, Mar. 2015.

[37] S. Vidya, S. Abinaya, G. Geetha Rajeswari, and N. Guna, "Automatic LPG leakage detection and hazard prevention for home security," in *Proc. 5th Nat. Conf. VLSI, Embedded, Commun. Netw.*, Apr. 2014.

[38] Sitan and A. S. A. Ghafar, "Liquefied petroleum gas (LPG) leakage detection and monitoring system," *J. Sci. Technol.*, vol. 10, no. 3, 2018.

[39] P. R. Shinde, A. T. Khore, A. T. Hirave, V. R. Kaushik, and S. N. Divekar, "Automatic LPG cylinder booking and leakage detection using Arduino UNO," *Int. J. Sci. Res. Sci. Eng. Technol. (IJSRSET)*, vol. 7, no. 3, 2020.

[40] P. A. Jolhe, N. S. Potdukhe, and N. S. Gawai, "Automatic LPG booking, leakage detection and real-time gas measurement monitoring system," *Int. J. Eng. Res. Technol. (IJERT)*, vol. 2, no. 4, Apr. 2013.

[41] Salmani, “LPG gas leakage detection & control system,” *Bonfring Int. J. Softw. Eng. Soft Comput.*, vol. 6, Special Issue, Oct. 2016.

[42] M. Priya, M. Surekha, R. Preethi, T. Devika, and N. Dhivya, “Smart gas cylinder using embedded system,” *Int. J. Innov. Res. Electr., Electron., Instrum. Control Eng.*, vol. 2, no. 2, Feb. 2014.

[43] Khan, “Sensor-based gas leakage detector system,” in *7th Int. Electron. Conf. Sensors Appl.*, Nov. 2020.

[44] Anuradha, R. R. Arabelli, K. Rajkumar, and J. Ravichander, “Microcontroller based monitoring and controlling of LPG leaks using Internet of Things,” *IOP Conf. Ser.: Mater. Sci. Eng.*, vol. 981, 2020.

[45] V. Suma, R. R. Shekar, and A. K. A., “Gas leakage detection based on IoT,” in *Proc. Int. Conf. Electron., Comput. Commun. Appl. (ICECA)*, 2019.

[46] I. Hossain Siddika, “LPG gas leakage monitoring and alert system using Arduino,” *Int. J. Sci. Res. (IJSR)*, vol. 9, no. 1, Jan. 2020.

[47] Evalina and A. Azis H., “Implementation and design gas leakage detection system using ATMega8 microcontroller,” in *Proc. Int. Conf. Eng. Appl. Technol.*, 2019.

[48] Dewi and Y. Somantri, “Wireless sensor network on LPG gas leak detection and automatic gas regulator system using Arduino,” in *Proc. Int. Symp. Mater. Electr. Eng. (ISMEE)*, 2017.

[49] M. I. Bello Baballe, “Gas leakage detection system with alarming system,” *Rev. Comput. Eng. Res.*, vol. 9, no. 1, pp. 30–43, 2022.

[50] S. T. Apeh, K. B. Erameh, and U. Iruansi, “Design and development of kitchen gas leakage detection and automatic gas shut off system,” *J. Emerg. Trends Eng. Appl. Sci. (JETEAS)*, 2014.

[51] Zinnuraain, M. H. Hasan, M. A. Hakque, and M. M. N. Arefin, “Smart gas leakage detection with monitoring and automatic safety system,” unpublished.

[52] Y. M. Mohialden, N. T. Ahmed, M. A. Mohammed, and T. Sutikno, “A smart gas leakage monitoring system for use in hospitals,” *Indones. J. Electr. Eng. Comput. Sci.*, vol. 19, no. 2, pp. 1072–1079, Aug. 2020.

[53] T. Devi B. Kodal and S. C. Rajanarayanan, “IoT based automatic LPG gas booking and leakage detection system,” in *Proc. Int. Conf. Adv. Comput. (ICoAC)*, 2020.

[54] S. Karmokar and M. I. H. Rana, “A smart approach of LPG monitoring and detection system using IoT,” unpublished.

[55] A. B. Nasir, A. M. Hassan, and N. M. Tahir, “Development of a gas leakage detector with temperature control system,” *J. Multidiscip. Eng. Sci. Technol. (JMEST)*, vol. 6, no. 12, Dec. 2019.

[56] Sriwati, N. Ikhsan Ilahi, Musrawati, S. Baco, A. Suyuti, A. Achmad, and E. Umrianah, "Early leakage protection system of LPG (liquefied petroleum gas) based on ATMega 16 microcontroller," *IOP Conf. Ser.: Mater. Sci. Eng.*, vol. 336, p. 012021, 2018.

[57] S. A. C. Abdullah, M. A. Shafie, and M. N. Ibrahim, "Home and industrial safety IoT on LPG gas leakage detection and alert system," *Int. J. Adv. Soft Comput. Appl.*, vol. 11, no. 1, Mar. 2019.

[58] T. W. Lai and A. Moe, "IoT based LPG gas level detection & gas leakage accident prevention with alert system," *Balkan J. Electr. Comput. Eng.*, vol. 9, no. 4, Oct. 2021.

[59] J. Pradeep, H. R., and P. Prahatheesh, "Smart LPG cylinder monitoring and explosion management system," in *Proc. Int. Symp. Adv. Topics Electr. Eng. (ATEE)*, 2021.

[60] M. R. Islam, A. Matin, M. S. Siddiquee, F. M. S. Hasnain, M. H. Rahman, and T. Hasan, "A novel smart gas stove with gas leakage detection and multistage prevention system using IoT-LoRa technology," in *Proc. IEEE Electr. Power Energy Conf. (EPEC)*, 2020.

[61] A. M. Anika, M. S. Nasrin Akter, M. D. N. Hasan, J. F. Shoma, and A. Sattar, "Gas leakage with auto ventilation and smart management system using IoT," in *Proc. Int. Conf. Artif. Intell. Smart Syst. (ICAIS)*, 2021.

[62] D. T. Mary J, M. Sindhu, T. B. Mary I, and J. Paul, "Microcontroller based gas leakage detection with SMS alert and automatic locking system," in *Proc. Int. Conf. Signal Process. Commun. (ICSPC)*, Mar. 2019, Coimbatore, India.

[63] A. Kumar, M. Kumar, and B. Singh, "Designing and implementation of smart LPG trolley with home safety," in *Proc. Int. Conf. Next Gener. Comput. Technol. (NGCT)*, Dehradun, India, Oct. 14–16, 2016.

[64] R. M. I. U. Rajapaksha, P. S. H. Perera, P. K. D. M. Nandasena, P. S. T. K. Gunarathna, P. P. D. G. Kanishka, A. L. A. K. Ranaweera, and S. R. D. Kalingamudali, "Design of an auto disconnecting regulator and a safety switch to prevent domestic gas leakages," unpublished.

[65] S. Kishor, J. S. Gurupadappa, and N. V. Nanjundaradhya, "Smart LPG leakage detection and control system,"

[66] I. Jafar, Z. A. Alkhalesi, J. Al-Naffakh, and M. R. Al-Qassab, "Remote monitoring and control of residential gas valves via IoT connectivity," *J. Res. Technol. Eng.*, vol. 4, no. 4, pp. 76–87, 2023.

[67] Haryanto, L. Anifah, D. Rahmawati, A. K. Sahputra, and D. T. Laksono, "Smart controlling system for kitchen fire protection based on Internet of Things," in *Workshop on Environmental Science, Society, and Technology (WESTECH)*, 2020.

[68] I. Triyatno and A. Yudhana, “Protection and monitoring system for LPG leaks and fires in Arduino-based rooms,” *J. Electr. Eng. Comput. Sci.*, vol. 5, no. 1, pp. 31–40, Mar. 2023.

[69] “Mirpur gas explosion death toll rises to 5,” *Dhaka Tribune*, Dec. 14, 2024. [Online].Available: https://www.dhakatribune.com/bangladesh/dhaka/368124/mirpur-gas-explosion-death-toll-rises-to-5

[70] “Two killed, 7 hurt in CNG filling station blast,” *The Daily Star*, Nov. 5, 2024. [Online]. Available: https://www.thedailystar.net/news/bangladesh/accidents-fires/news/two-killed-7-hurt-cng-filling-station-blast-3744596

[71] “Gas explosion incident,” *bdnews24.com*, Oct. 14, 2024. [Online]. Available: https://bdnews24.com/bangladesh/2ce8c647e6bd

[72] “One killed in gas cylinder explosion at Dhamrai CNG station,” *The Business Standard*, Oct. 18, 2024. [Online]. Available: https://www.tbsnews.net/bangladesh/1-killed-gas-cylinder-explosion-dhamrai-cng-station-969776?amp

[73] M. A. S. Rabby, "Fire safety measures a must for all buildings," *The Daily Observer*, Jun. 24, 2024. [Online]. Available: https://www.observerbd.com/news/465065

[74] “LPG blast coverage,” *bdnews24.com*, [Online]. Available: https://bdnews24.com/bangladesh/xfwhq9mbgl

[75] “Article on LPG safety,” *Energy & Power*, [Online]. Available: https://ep-bd.com/view/details/article/MzIwNQ%3D%3D/title

[76] “LPG accident report,” *bdnews24.com*, [Online]. Available: https://bdnews24.com/bangladesh/b6hj0t4qyd

[77] “Who is responsible for LPG accidents?” *Energy & Power*, [Online]. Available: https://ep-bd.com/assets/images/ep-bd-who is Responsible for LPG Accidents

[78] “Gas accident news,” *Daily Messenger*, [Online]. Available: https://www.dailymessenger.net/bangladesh/news/15387

[79] “10 burnt in fire caused by gas cylinder leak in Ashulia,” *The Daily Star*, [Online]. Available: https://www.thedailystar.net/news/bangladesh/accidents-fires/news/10-burnt-fire-caused-gas-cylinder-leak-ashulia-3393251

[80] “4 family members burnt in gas explosion,” *Dhaka Tribune*, [Online]. Available: https://www.dhakatribune.com/bangladesh/334115/4-family-members-burnt-in-gas-explosion-in

[81] "Seven youths injured in Savar gas leak explosion," *Dhaka Tribune*, [Online]. Available:https://www.dhakatribune.com/bangladesh/nation/331416/seven-youths-injured-in-savar-gas-leak-explosion

[82] "LPG explosion case study," *Energy & Power*, [Online]. Available: https://ep-bd.com/view/details/article/MzIwNQ%3D%3D/title

[83] "Mumbai's Dharavi shaken as 20 LPG cylinders on truck explode," *The Times of India*, [Online]. Available: https://timesofindia.indiatimes.com/city/mumbai/mumbais-dharavi-shaken-as-20-lpg-cylinders-on-truck-explode/articleshow/119452323.cms

[84] M. S. Chowdhury, F. Junaky, M. A. Amin, S. K. Pal, M. Rokonuzzaman, and M. M. Rahman, "An assessment of the level of safety awareness among the LPG consumers in Dhaka city," Bangladesh, Apr. 30, 2020.

[85] Bangladesh Fire Service and Civil Defense (BFSCD), *Annual Report and Statistics*, 2017–2023.

[86] "LPG Safety and Usage Information," *Elgas Australia*, [Online]. Available: https://www.elgas.com.au/blog/1976

[87] "Home LPG gas regulators and fittings," *Elgas Australia*, [Online]. Available: https://www.elgas.com.au/blog/404-home-lpg-gas-regulators-and-fittings

[88] P. Shahi, "Factors influencing the adoption of smart-home appliances: Users' perspectives," unpublished.

[89] U.S. Energy associated with the increasing use of liquefied petroleum gas," *J. Failure Anal. Prev.*, vol. 10, pp. 323–333, 2010.Information Administration (EIA), IEA Bioenergy, World Nuclear Association, Various Reports.

[90] "A study on optimum ratio of propane and butane mixture in LPG and effect of impurities for different usage," *BPI Report*, Dhaka, May 2022.

[91] "Gas LEL Charts," *Sensing.fi*, [Online]. Available: https://sensing.fi/en/gas-list/lel-charts

[92] S. M. Tauseef, T. Abbasi, and S. A. Abbasi, "Risks of fire and explosion

[93] L. Sinagal, S. Nafisah, K. S. Suhaimi, and M. A. Shani, "Design and implementation of LPG leakage detection system using IoT-based regulator lever automation on a household scale," *J. Ecotipe*, vol. 11, no. 2, DOI: 10.33019/jurnalecotipe.v11i2.4496.

[94] B. Kommey, D. Opoku, J. Lartey, K. Kumah, and M. Tantuo, "A simple, low-cost, efficient and smart consumer gas leakage detection system," *Int. J. Informatics Inf. Syst. Comput. Eng.*, vol. 3, no. 1, pp. 109–113, 2022.

[95] H. Darus, S. A. Seman, and N. D. Keraf, “Smart LPG regulator,” *J. Water Environ. Resour. (JWER)*, vol. 1, no. 1, Art. no. a0000515, 2024. [Online]. Available: https://doi.org/10.36877/jwer.a0000515

[96] J. B. Karande and S. G. Suryavanshi, “Smart and reliable LPG regulator design using Internet of Things,” in *Proc. IEEE*, 2017, doi: 10.1109/ICECDS.2017.8389786.

[97] *Cause Analysis of Gas Leaks and Methods to Limit Leakage*, Bachelor Thesis, Stord/Haugesund University College – Engineering, Norway.

[98] E. M. Saleh, T. Imbarake, S. Elakeili, and A. G. Faraj, “Smart gas leakage detection system for home safety,” in *Proc. 14th Int. Conf. Adv. Comput. Inf. Technol. (ACIT)*, 2024.

[99] G. A. Senthil, P. Suganthi, R. Prabha, M. Madhumathi, S. Prabhu, and S. Sridevi, “An enhanced smart intelligent detecting and alerting system for industrial gas leakage using IoT in sensor network,” in *Proc. Int. Conf. Smart Syst. Inf. Technol. (ICSSIT)*, 2023.

[100] T. Babu, R. R. Nair, K. S. Kishore, and M. Vineeth, “Enhancing gas leak detection with IoT technology: An innovative approach,” in *Proc. Int. Conf. Mach. Learn. Data Eng. (ICMLDE)*, 2023.

[101] S. S. S. Subri, N. M. Zaki, and R. Ramli, “A critical review on LPG gas leakage detection and monitoring system,” *J. Social Sci. Tech. Educ. (Jurnal Sains Sosial dan Pendidikan Teknikal)*, vol. 2, no. 2 (Special Issue), pp. 1–14, 2021.

[102] Javaid, Z. Ullah, Z. Zaheer, M. Raza, M. Khalid, G. Ahmed, and S. Khan, "Energy efficient multi-attribute based clustering scheme for energy harvesting wireless sensor networks," *Int. J. Distrib. Sens. Netw.*, vol. 16, no. 10, pp. 1–12, 2020, doi: 10.1177/1550147720968047.