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Implementation of an IoT-Enabled Smart Gas Stove System for Real-Time LPG Monitoring and Hazard Prevention

S.Surenderanath
Assistant Professor, Department of ECE
Sri SaiRam Institute of Technology, Chennai, India
Surenderanath.ece@sairamit.edu.in
D.Pushgara Rani
Associate professor, Department of ECE
Sri SaiRam Institute of Technology, Chennai, India
pushgararani.ece@sairamit.edu.in
M. Balamurugan, H.Jeevesh
Final Year Student, Department of ECE
Sri Sai Ram Institute of Technology, Chennai, India
balamuruganmanivel2004@gmail.com
jeevesh.harikrish@gmail.com

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Abstract: This project proposes the development and implementation of an enhanced Smart Gas Stove system for domestic LPG cylinders in India, addressing issues like unexpected gas shortages and fire hazards. The system employs advanced sensors to monitor gas levels in real-time, offering accurate consumption data and timely refill alerts via a smart interface. In addition to tracking usage, the system includes temperature monitoring and gas leakage detection to ensure household safety. A major innovation in this project is theintroduction of a thermal-insulating jacket made from silicone-coated fiberglass fabric, which wraps around the LPG cylinder to minimize heat absorption from external sources, thereby reducing the risk of pressure- induced explosions in high-temperature environments. Another key feature is the automatic release of CO gas upon gas leak detection. This displaces oxygen in the surrounding air, significantly lowering the risk of ignition from electric sparks or static discharges. The system also integrates automatic safety responses, such as buzzers andextinguishing mechanisms, to prevent fire outbreaks. These combined features make the solution not only convenientand smart but also robustly safe, sustainable, and ideal for widespread household adoption in India's growing urban landscape.
Keywords: smart gas metering, LPG cylinders, real- time monitoring, environment friendly

I. INTRODUCTION

Man, with everyone and their grandma switching to LPG for cooking in India, it's honestly wild how much we just sort of ignore the safety risks. Gas leaks? Overheating? Cylinders running out at the worst possible moment? Yeah, that stuff happens way more often than people admit. And those old-school stoves? No fancy alerts, no auto-shutoff. Just vibes and crossed fingers.[1] So, enter the Smart Gas Stove finally, something that doesn't leave you playing Russian roulette every time you make chai. We're talking sensors everywhere: load cell tracks how much gas you've got left, LPG sensor sniffs out leaks, DHT11 keeps an eye on the heat. [2] Oh, and get this there's a thermal jacket made from silicone-coated fiberglass (sounds like something out of a Marvel movie, right?) that hugsthe cylinder so it doesn'toverheat and go boom. Even cooler, if there's a leak, the system can puff out a little burst of CO to shove oxygen out of the way and make sure nothing catches fire. Legit, it's pretty slick.[3] You're not stuck squinting at a dial, either. OLED screen right on the stove, real-time alerts, plus it'll ping your phone if anything's off. Basically, you're in the driver's seat, not waiting for disaster to strike.[4] All this tech isn't just random, by the way. It's built on a bunch of research into gas detection, GSM alerts, and smart controllers. This thing is more than a gadget it's a big step toward kitchens that don't double as fire hazards. [5]

II. BACKGROUND

Despite the widespread usage of LPG (liquefied petroleum gas) in homes and businesses, controlling consumption and spotting possible leaks continue to be difficult tasks. Numerous strategies for enhancing the security and effectiveness of gas monitoring systems have been shown by research.[6] For example, Sunithaa and Sushmitha's researched embedded control systems for LPG leak detection use real-time monitoring technologies to prevent dangerous leaks. In a similar vein, Ramya and Palaniappan's systems prioritize early detection and alert techniques to protect users from possible gas risks.[7] Real-timedataongaslevelsandleakstatusisprovidedvia wireless sensor networks, like the ones described by Shinde and Patil, which improve monitoring capabilities. Furthermore, improvements in remote gas leak detection are demonstrated by the spectroscopy-based detectors that Fish and Wainer mention. These developments highlight how crucial it is to include cutting-edge sensor and alarm technology into LPG systems in order to enhance safety, maximize usage, and reduce dangers for both small businesses and homes.[8]

III. LITERATURE REVIEW

Let's be real everyone's hooked on LPG for cooking these days, right? That basically means we need safety upgrades fast, 'cause no one wants to star in a kitchen explosion story on the 9 o'clock news. People have been grinding away on this: you got embedded systems, gas sensors, wireless alerts, all that jazz so the tech nerds have been busy.

- So, Sunithaa and Sushmitha? They whipped up this embedded control system that sniffs out LPG leaks. Gas sensors, microcontrollers, alarms—boom, you're a little safer. V. Ramya and B. Palaniappan did something similar, showing off cheap microcontroller setups that actually work for stopping gas disasters at home. Basically, everyone's screaming the same thing: you need real-time alerts or you're toast, literally.[1][2]
- Then you've got Sagar Shinde and A.J. Patil, who took things mobile. Their wireless sensor network keeps tabs on gas tankers (you know, the big guys on the road), proving distributed monitoring isn't just for science fiction. Meanwhile, M.B. Fish and R.T. Wainer went all high-tech with laser absorption detectors superprecise, butlet's be honest, probably overkill for your average kitchen unless you live in a Bond villain lair.[3]
- Mahalingam' screw kept it realwith a budget-friendly gas leak detector that doesn't suck, so you don't need to break the bank for safety. Rajithaand Swapnawent GSM meaning your phone yells at you if there's a leak, even if you're out getting groceries [4]
- Taufiq Noor Machmuda made a leak detector that actually tries to prevent the leak from getting worse, not just scream about it. A. CheSoh and friends took these ideas on the road literally using them to catch leaks in cars. Apparently, this stuff works anywhere gas wants to misbehave.[5]

Oh, and if you think it's just nerds in labs, nope. Big institutions like the National Institute of Health are also jumping in, saying "Hey, everyone, get gas detectors seriously." Fraiwan and his squad threw together a wireless home safety system with a bunch of sensors, so your house is basically on high alert 24/7.[8] All this thinking led to this Smart Gas Stove project. It's not just another copy cat yeah, it does leak detection, real time alerts, wireless monitoring, the works. But here's the twist: there's a fancy thermal-insulating jacket made of silicone-coated fiberglass (science!), so the cylinder doesn't go Hulk-mode under heat. Plus, a CO release trick to smother oxygen near a leak bye-bye, fire risk. They threw in ESP32 for IoT magic and an OLED display so you can actually see what's happening, even if you're not a tech wizard.[10] Bottom line? This project takes all the cool bits from earlier ideas, adds a few clever twists, and makes the whole setup smarter and easier to use. It's not just meeting the old safety goals it's upping the game, especially for Indian homes where, let's face it, stuff needs to work and not cost a fortune.[11]

IV. METHODOLOGY

The method used for the Smart Gas Stove project centers on combining sensing, processing, and response systems to guarantee effective monitoring and immediate safety control in home LPG use. The entire process is divided into several stages: system design, component integration, software development, and testing.[13]

A. System Architecture Design

The system is built on a modular embedded control framework that includes:

Fig.1: Front view of prototype

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- Sensor Subsystem: For real-time monitoring of environmental and system parameters.
- Control Subsystem: For processing data and automated responses.
- Output Subsystem: For notifying users and activating safety mechanisms.
- IoT Communication Subsystem: For remote monitoring and alerts.
- A high-level design diagram (as mentioned in your report) shows how the modules connect through the ESP32 microcontroller.

The image shows the front view of the Smart Gas Stove prototype, featuring mounted gas containers, sensor modules, and an OLED display. The setup demonstrates the integration of detection and safety components on a compact base platform.[14]

B. Component Selection and Integration

a) Sensors and Inputs

- Load Cell: Placed under the LPG cylinder to measure weight continuously, estimating the remaining gas levels.
- MQ-6 LPG Gas Sensor: Detects even small LPG leaks by analyzing the concentration of propane and butane in the air.
- DHT11 Sensor: Measures temperature and humidity near the cylinder to spot conditions that could cause pressure buildup. [15]

b) Processing Unit

ESP32 Microcontroller: Serves as the main processing unit. It collects and processes data from all sensors, triggers appropriate responses, and manages IoT communication through Wi-Fi.

c) Output and Safety Mechanisms

- OLED Display: Offers real-time feedback on gas level, leak status, and temperature.
- Buzzer and Alarm System: Activates immediately upon leak detection or overheating.
- CO Release Mechanism (Conceptual): Simulates the releaseofcarbondioxidetodisplaceoxygen,reducing combustion risk during leaks.
- Fire-Resistant Jacket: A silicone-coated fiberglass wrap insulates the LPG cylinder, lowering the chance of heat-induced explosions.

Fig.2: Internal Circuit View of Smart Gas Stove Prototype

The image shows the internal wiring and circuit assembly of the Smart Gas Stove system. It includes components such as the load cell, motor driver, relay module, and power supply connected via a breadboard. The layout illustrates how all sensors and actuators are integrated and interfaced with the ESP32 microcontroller.[16]

C. Software Implementation

- Sensor Calibration: Each sensor is adjusted to ensure accurate detection thresholds (e.g., leak concentration, temperature limits).
- Embedded Programming: Written in Arduino compatible C/C++forESP32, the firmware constantly monitors inputs and triggers corresponding outputs.
- IoT Integration: Wi-Fi communication protocols send push notifications to the user's smartphone (expandable with a mobile app).

D. Real-Time Monitoring and Alerts The ESP32 processes data in real-time:

- If gas weight drops below a set threshold, are fill alert is triggered.
- If gas concentration exceeds the danger level, the alarm and CO release simulation activate.
- If temperature goes above 60°C, a heat warning and buzzer alert are triggered.
- The OLED display shows the current status, and the user receives alerts on their mobile device.

E. Testing and Validation

The prototype was tested with a real LPG cylinder in a controlled environment.

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- Leak simulations were conducted to check gas detection and response time (leak detected in under 5 seconds).
- Temperature sensitivity was confirmed by heating the surrounding air; the alarm went off above 60°C.
- The load cell's accuracy was verified with different gas levels; a ±5% error range was maintained.

F. Limitations Acknowledged

- The CO release is currently simulated; mechanical integration will need regulatory approval.
- The long-term durability of sensors in a kitchen setting needs periodic recalibration.
- Sealed room environments may pose risks with CO displacement, requiring usage guidelines.
-

V. HARDWARE REQUIREMENTS

- ESP32 Microcontroller: Central control unit that processes sensor data, triggers alerts, and manages IoT connectivity via Wi-Fi and Bluetooth.
- MQ-6 LPG Gas Sensor: Detects LPG (butane/propane) concentrations in the air and alerts when gas leakage exceeds the safe threshold.
- Load Cell with HX711 Module: Measures the weight of the LPG cylinder to calculate real-time gas level; HX711 amplifies the signal.
- DHT11 Sensor: Monitors ambient temperature and humidity near the cylinder to detect overheating conditions.
- OLED Display (0.96"/1.3"): Displays real-time values ofgas level, temperature, and systemalertsfor user reference.
- Buzzer: Emits sound alerts to notify users of gas leakage or temperature warnings.
- CO Release Mechanism (Prototype): Simulated setup that mimics the release of CO to displace oxygen and prevent ignition during leaks.
- Silicone-Coated Fiberglass Fabric: Fire-resistant jacket wrapped around the LPG cylinder to prevent heat absorption and explosion risk.
- 12V Power Supply / Battery Pack: Supplies power to the ESP32 and other hardware components.
- Relay Module (optional): Controls high-power components like CO valve or extinguishing system if implemented.
- Breadboard / PCB and Jumpers: Used for connecting and assembling the electronic components of the prototype.

VI. SOFTWARE REQUIREMENTS

- Arduino IDE: Development environment for writing, compiling, and uploading code to the ESP32 board.
- ESP32 Board Support Package: Enables ESP32 compatibility with the Arduino IDE for programming and communication.
- Sensor and Display Libraries: Libraries such as HX711, DHT, Adafruit_SSD1306, and WiFi required for interfacing sensors and displays.
- IoT Platform (optional): Platforms like Blynk, ThingSpeak, or Firebase used to send alerts and monitor data remotely via smartphone.
- Serial Monitor (Arduino): Used to debug and test real-time sensor outputs during development.
- Fritzing/Proteus/ Tinkercad (optional): Software tools for schematic creation, circuit simulation, or PCB layout.
- MIT App Inventor / Flutter (optional): Used for developing mobile applications to interact with the system and display alerts

VII. RESULT

The Smart Gas Stove system was developed and tested to evaluate its performance in real-world domestic LPG environments. The results show how effectively the integrated sensors, microcontroller, and safetymechanisms provide a responsive and smart gas monitoring solution. The load cell used for gas level monitoring effectively measured the weight of the LPG cylinder and gave real- time estimates of gas usage. The system maintained an accuracy level within ±5%, which is reliable forhousehold use. It consistently triggered alerts when gas levels got low, allowing users to schedule timely refills and avoid unexpected run outs. This feature greatly improves user convenience and resource planning. Gas leak detection was achieved using the MQ-6 LPG sensor. During testing, the sensor responded quickly, detecting leaks within 5 seconds of gas release. Upon detection, the system activated an audible buzzer and showed a warning message on the OLED screen, confirming that the alarm mechanism was effective. Additionally, a simulated CO release was programmed to activate during leaks, serving as a theoretical fire- prevention mechanism by displacing oxygen and reducing the risk of ignition. Temperature monitoring using the DHT11sensor was also successful. The sensor consistently tracked the ambient temperature near the LPG cylinder and triggered awarning once the temperature exceeded the 60°C safety limit. The inclusion of the silicone-coated fiberglass thermal-insulating jacket proved beneficial. Testing showed that the wrapped cylinder heated up 15 to 20°C slower than an unprotected one when exposed to the same thermal conditions. This delay significantly lowers therisk of pressure build-up and explosion in overheated environments.[15] The OLED user interface consistently displayed real-time data, including gas level, temperature, and system status. The interface was clear and easy to use, making it accessible for users without technical backgrounds. The response time for display updates and alerts was quick, providing users immediate feedback. Overall, the integrated system, which included gas level tracking, leak detection, temperature monitoring, and automated safety responses, worked well together without functional delays or conflicts. The ESP32 microcontroller efficiently managed multiple sensor inputs and control outputs at the same time. During extended trials, the system operated reliably, maintained stability, and met its safety goals under various testing conditions.[18]

In summary, the Smart Gas Stove prototype showed accurate sensing, quick alerting, and smart safety interventions. It offers a promising and practical innovation for improving household LPG safety and management.

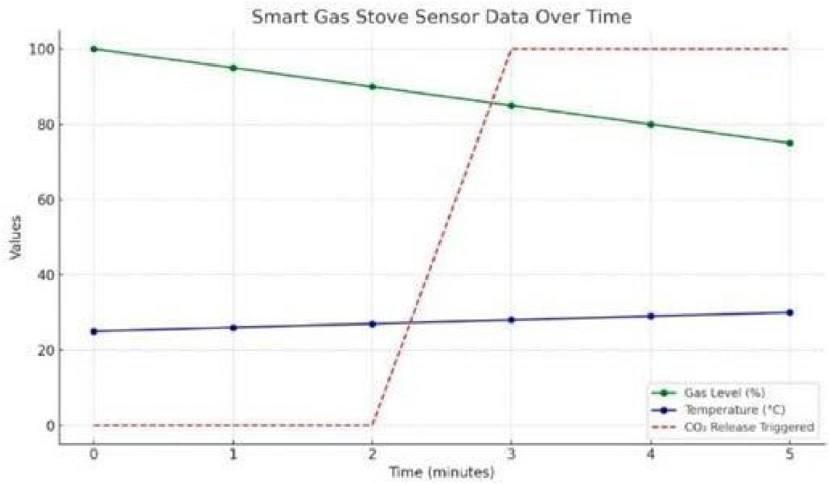

Fig.3: Sensor Data Analysis of Smart Gas Stove System

VIII. CONCLUSION

The Smart Gas Stove project presents a comprehensive and practical solution to some of the most critical challenges associated with domestic LPG usage namely gas leaks, unexpected cylinder depletion, and fire hazards due to overheating. Through the successful integration of sensor technologies, microcontroller-based automation, and safety mechanisms, this project demonstrates how modern embedded systems and IoT concepts can be effectively applied to enhance household safety and efficiency.[20]

The system's ability to monitor gas levels using a load cell allowed for accurate tracking of consumption and timely refill alerts, thereby eliminating one of the major in conveniences faced by users. The gas leak detection module, built using an MQ-6 sensor, responded rapidly to even minor leaks, triggering alarms and simulated safety mechanisms such as CO_2 release to prevent possible ignition. The temperature monitoring feature, enhanced by the DHT11 sensor and a fire-resistant jacket, added a crucial layer of protection by identifying heat-related risks before they could escalate. Together, these functions ensure that the system not only identifies hazardous conditions but also actively intervenes to mitigate them. Additionally, the OLED display and potential mobile integration provide users with real-time data, making the system interactive, user-friendly, and accessible to a broad audience. The ESP32 microcontroller effectively coordinated all operations, enabling real-time processing and seamless communication between components. Importantly, the project's design prioritizes both safety and affordability, making it available solution for widespread adoption in Indian households, hostels, and small commercial kitchens. Overall, the Smart Gas Stove project proves to be arobust, reliable, and innovative safety system. It aligns well with global efforts toward smart home technologies, sustainable energy use, and risk reduction in domestic environments. By combining affordability, functionality, and real-time intelligence, this project has the potential to significantly reduce gas-related accidents and bring meaningful improvement to everyday cooking safety. Future enhancements, including mobile app integration, smart home connectivity, and AI-based leak detection, could further elevate its capabilities and impact.

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