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IoT-Integrated Autonomous LPG Safety System

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Abstract:- Integrating IoT and AI has transformed household safety applications, bringing complexity to the design of user interface and experience, which presents a challenge in its own right. This paper develops a Smart LPG Trolley (SLT) framework that uses IoT and AI to enhance safety and usability in household LPG management. The objective encompasses real- time monitoring, automated shutdown mechanisms, and remote user interaction through AI-driven processes. Key technologies include machine learning and responsive mobile app interfaces developed on the MERN-Stack. The case study results from the development of SLT have shown improved safety, user engagement, and efficiency, which further supports the broader applications of AI-driven design in IoT solutions.

IoT, AI, Smart LPG Trolley, Real-time Monitoring, User-Centred Design, Gas leak detection, MERN-stack, Automated Shut-off, Human-centered design, Interaction design, Weight monitoring, Safety enhancement, Mobile application integration, Smart home system.

I. INTRODUCTION

The Increasing levels of using Liquefied Petroleum Gas as a domestic fuel has raised many issues, including gas leak-related problems and efficient consumption alongside resource management, and further emphasized the need for implementing suitable security safety systems. Available market solutions to achieve this, in the shape of leak detection or weight monitoring, are unidirectional and cannot provide an overall system with real-time management of safety. Introduce the Smart LPG Trolley, that is, the sophisticated IoT-and AI-based platform addressing limitations in terms of holistic automation for residential LPG safety and resource optimization.

In the SLT system, advanced IoT components have been integrated specifically to ensure that LPG use can be monitored precisely and continually. This unit incorporates a Piezoelectric Transducer that senses and provides real-time weight feedback of the LPG cylinder, which allows predictive anticipation of refilling requirements and prevents any discontinuities. Additionally, there is an MQ-6 gas sensor that picks up even tiny leaks in the gases, and it sends instant alarms to the user to save time in preventing safety risks. These core sensors are meant to gather the required information and will also make

Identify applicable funding agency here. If none, delete this the system allow for the sending of real-time alerts to users through a secure web-based application that will be engaged with and responsive to safety issues.

AI is the backbone of SLT, especially the emergency management feature. The system comes with an automatic shut- off mechanism that is AI-controlled, able to automatically stop the gas flow in case of detected hazardous conditions, such as an ongoing leak or low gas levels. This mechanism minimizes the need for user intervention and reduces human error, thus ensuring prompt responses to potential emergencies. This is how SLT takes care of the safety of your household environment while making it more convenient to use LPG.

A web application based on the MERN (MongoDB, Express, React, Node.js) Stack allows the user access to all the functionalities provided by SLT, enabling seamless interaction between the user and the LPG system. The application is designed to be extremely easy to navigate and includes a user-friendly interface. Using this application, a person can get real-time visualization of data, receive alerts for gas leaks or low gas levels instantaneously, and schedule refills very efficiently. Notifications can also be customized; the user can personalize alert settings according to individual preferences, which makes the system flexible and adaptable to diverse user needs. This interface ensures that household LPG management is not only safe but also user-centred and accessible.

SLT is also poised to move forward with more safety and efficiency features like the development of an insulating blanket for the cylinder, which will provide yet another layer of protection from external ignition sources igniting the leaked gas. Improvements planned for the web app are making it even more automated to increase its potential to be a fully autonomous household management tool integrated with broader smart home systems.

In a nutshell, the Smart LPG Trolley, or SLT, is one of the pioneering approaches in LPG management and demonstrates how IoT and AI technologies can revolutionize home safety practices. The SLT system addresses the shortcomings of current market solutions by integrating a comprehensive system of real-time monitoring, automated emergency response, and a user-friendly application. This innovation sheds light on the possibility of AI-driven tools in optimizing household LPG usage, reducing risks, and ensuring sustainable and efficient

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resource management practices.

II. RELATED WORK

- Panse et al., 2018 report on an IoT Based Smart Gas Monitoring System that focuses on using IoT sensors for gas leak detection. They highlight the system's real-time alert capabilities, which provide timely warnings to users. However, their work is limited to gas leakage detection, lacking integration with weight monitoring or other safety features.
- Bhosale et al., 2017 explore a Wireless LPG Gas Monitoring System, emphasizing wireless monitoring of LPG cylinder weight. The system's primary advantage is its ability to transmit data wirelessly, but it does not incorporate AI, limiting its functionality in automated safety measures and emergency response.
- Sharma et al., 2018 discuss an Automated LPG Cylinder Monitoring System using IoT for weight monitoring. Their system offers efficient tracking of gas consumption, allowing users to monitor usage trends. Despite its benefits, the high cost of hardware limits accessibility and scalability for broader consumer use.
- Prasad et al., 2017 present a Real-Time LPG Gas Monitoring System using IoT that supports continuous monitoring. This solution enables users to track gas levels in real time, though it lacks mobile app integration for remote alerts, which restricts its convenience and usability for households.
- Singh et al., 2019 introduce a Smart Gas Leakage Detector System utilizing gas leak sensors with GSM modules. They highlight the cost-effectiveness of their solution for basic leak detection, but it does not provide weight monitoring, resulting in a partial solution for LPG management.
- Roy et al., 2020 propose an IoT Based Safety System for LPG, using GSM-based alerts to notify users of potential gas leaks. Their work emphasizes simplicity and effectiveness in alerting, yet lacks remote gas flow control, limiting user interaction and safety management in emergencies.
- Patel et al., 2021 investigate AI-Powered Gas Safety Systems, which integrate AI and IoT for improved gas safety. Their advanced AI features enhance emergency handling, yet the system faces challenges in complex implementation and high setup costs, affecting its accessibility for average consumers.
- Ali et al., 2020 explore Smart Homes: Gas Monitoring, focusing on integrating mobile apps with IoT for gas monitor- ing. They emphasize the user-friendly nature of their interface, allowing remote monitoring, though the system remains costly due to the advanced IoT components used.
- Khan et al., 2022 report on an IoT and AI for Gas Management system that adopts a hybrid AI-IoT approach. The authors show that their system offers high safety and automation capabilities; however, it is hindered by high initial costs and scalability challenges, making it less feasible for widespread adoption.
- Kumar et al., 2021 present IoT-Based LPG Systems aimed at enhancing safety and efficiency in LPG usage. Their system is multi-functional, utilizing various sensors for monitoring. While effective, limited scalability restricts its use in larger applications beyond the household setting.
- Johnson et al., 2019 describe a Smart LPG Leak Detector Using IoT, focused on reliable real-time leak alerts. This solution offers immediate feedback during gas leaks but does not cover weight monitoring, providing a limited approach to comprehensive LPG management.
- Maheshwari et al., 2020 introduce Automated Gas Cylinder Safety Systems with an automated shut-off feature. This system improves safety by stopping gas flow in emergencies. However, it lacks mobile integration, which could limit timely notifications and user response.
- Sahoo et al., 2021 analyze IoT Applications in Gas Management with an emphasis on continuous monitoring and leak detection. Their system ensures consistent gas level monitoring, though it does not include emergency handling or shut-off mechanisms, restricting its safety measures.
- Chopra et al., 2020 explore a Gas Leakage and Cylinder Monitoring System Using IoT, emphasizing remote monitoring and alerting. While users receive timely notifications through IoT-based alerts, the system does not incorporate weight track- ing, which limits its functionality for full gas management.
- Verma et al., 2021 discuss IoT-Enhanced Gas Detection and Safety Systems that improve safety through a multi-sensor setup for gas leaks. Their approach emphasizes safety, but the lack of mobile app integration or user control features reduces its overall utility in daily household use.

III. EXISTING METHODOLOGY

Current LPG management systems, although sufficient for the purpose of simple functionality, are mostly concentrated on isolated tasks such as gas leak detection or weight monitoring. These systems have serious limitations in terms of coverage, connectivity, usability, and integration, which makes them less effective and less responsive to user needs. The next section provides a detailed discussion of the key challenges that exist in current systems.

A. Limited Coverage

Current LPG management systems are usually confined to limited ranges of their IoT components. Such examples include wireless modules or sensors, which usually operate through short-range communication and hence, limit their application areas within a particular room or confined area. This range confines the use in many instances to areas next to the LPG cylinder; the user cannot access it if they are out of their rooms or house.

This lack of extended range has several consequences: Reduced Safety: Users may not get real-time alerts if they step out of the device's range, thus increasing the chances of safety risks in the case of leaks or low LPG levels. Scalability Issues: Systems with limited ranges are harder to scale for larger or multi-story buildings where sensors and communication modules need to cover more areas. -Reliability Constraints: With such limited coverage, the reliability of these systems is reduced, since they cannot guarantee constant monitoring when users are not within close proximity. This lack of range is a major limitation for larger properties or commercial uses. To address these coverage issues, the current systems would require advanced IoT components with a wider range, such as long-range communication protocols (LoRaWAN) or cellular connectivity, which would enable monitoring and control over larger spaces.

B. Low Data Connectivity

The other main challenge is invariable data connectivity within the traditional LPG management systems currently in use. Most of such systems work off cloud network-based arrangements and end up struggling to connect most of the time due to: Bandwidth constraints: These devices have fewer bandwidth limits and hence take several seconds and more to carry out basic processes and this leads to late transmission of fundamental data towards the cloud center. Latency: High latency may not allow real-time data processing, and therefore an alert about a leak would reach the user after time. Network Reliability: In regions with poor network reliability, cloud-based systems can even lose connectivity, thus blocking data transmission and risking the safety of users. -Packet Loss: The data transmission instability can lead to packet loss, where data fails to reach the intended destination, thus leaving gaps in monitoring and recording.

These connectivity-related issues lead to a list of reliability problems. This means that some missed critical alerts of gas leakage may result because the system could, for a time, shut down its connectivity. Inconsistent connectivity could lead to the inaccessibility of some data stored in the cloud. This reason will cause users to lose confidence in the performance of the system, and sometimes, they will need to check LPG levels or safety status manually after all automation 3 has been defeated for this reason.

Most of the existing LPG management solutions do not have an interactive user-friendly visual interface, like a mobile ap- plication or web portal, where users can conveniently monitor data in real-time. In the absence of an interactive interface, users are only partially allowed to access crucial information, such as:

Gas Level Tracking: Users often cannot see the current LPG level, which makes planning for refills hard. Leak Alerts: Even in those systems that report the leaks with text or audio signals, the users do not have a dashboard showing the status and history of the leak. -System Health: There is no facility to depict how the different components of the system such as sensors might be deteriorating and impact safety over time.

Without such visual monitoring, users will likely miss crit- ical safety or operational insights and only rely on infrequent alerts, rather than having constant, real-time monitoring. This will minimize user interaction and also minimize the system's ability to ensure a safe and efficient household environment. A visual interface would, therefore, allow users to see real- time data, historical records, and even predictive insights at a glance, thereby making the system more transparent and effective.

C. Integration Problems

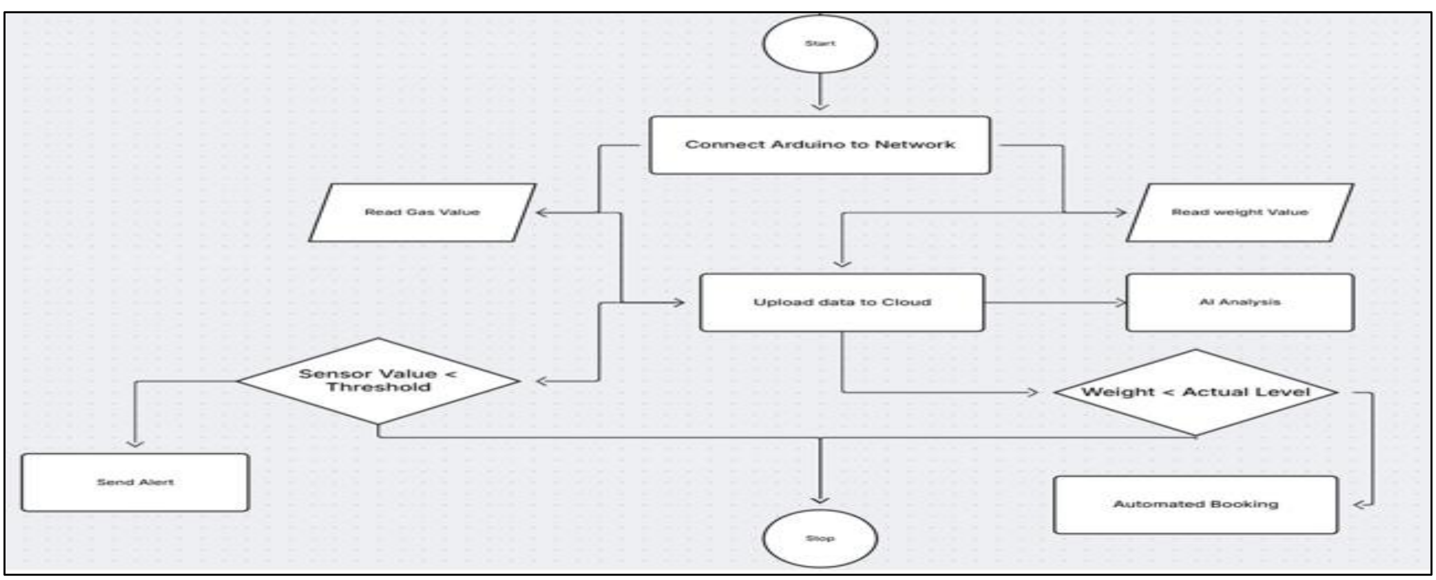

Fig 1: Work Flow Dig

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One of the core problems with current systems is the problem of integrating hardware and software components into a cohesive framework. IoT-based LPG systems are usually made up of multiple components, including sensors, communication modules, and cloud storage, all of which need to work in harmony. The following areas present integration issues: -Hardware-Software Compatibility: The various components have differences in protocols and standards; hence, a smooth interaction is quite challenging, and compatibility problems mostly arise. -Data Synchronization: Data from multiple sensors, such as weight, gas levels, and leaks, do not synchronize well with cloud storage, and thus partial and inconsistent records remain. -Error Handling: The lack of cohesive integration can lead to connectivity errors concerning data or transmission failures and reduce the system's responsiveness and reliability. Many existing systems fail to easily integrate with broader IoT ecosystems or smart home platforms; hence, their functionality may be limited, preventing a fully interconnected user experience through the system.

Integration challenges have compromised the usability and scalability of currently available LPG management solutions. Users may often experience frequent system errors or connec- tivity problems that make it difficult to maintain their trust in the system's performance during monitoring. Therefore, for future designs, the sensor-cloud-user interface integration must communicate without any problem, so standardized protocols and modular integration frameworks will be required.

IV. PROPOSED SOLUTION SMART LPG TROLLEY SLT

Connecting to IoT and AI, this SLT will provide us with an efficient and safe solution for handling an LPG cylinder inside one's house. Instead of only existing safety LPG solutions which give more features like real-time monitoring, automated emergency shut down and mobile applications on their own where users receive rather useful safety alerts as well as insights into the actual consuming patterns of their gases.

A. Problem Analysis and Solution Requirements

Household LPG use poses huge risks because of the presence of gas leaking, overusing cylinders, and the danger of explosion. Most solutions so far in the market are not so effective in real-time monitoring and automated response, hence putting users at their mercy. SLT addresses these ills with three main objects:

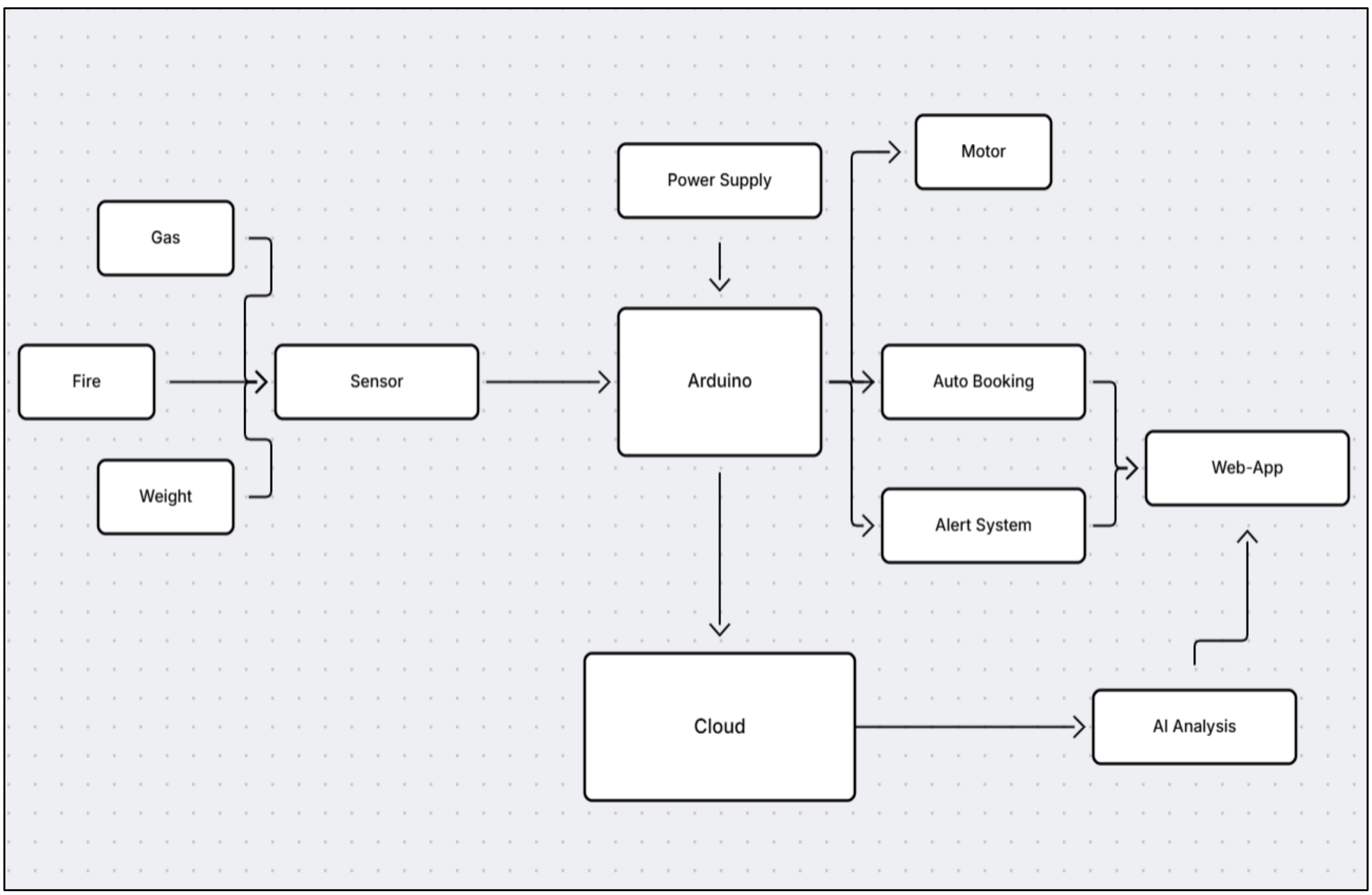

Fig 2: System Architecture Dig

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- *Gas Leak Detection*: The SLT continuously scans for gas leaks using the MQ-6 sensor. This sensor has a very high sensitivity level to LPG and other gases, making it an effective selection for detecting potential leaks at a fast and accurate rate. This allows the system to immediately warn users, potentially saving them from dangerous situations.
- *Weight Measurement*: This has a piezoelectric transducer, which is utilized in weighing the LPG cylinder so that the amount of remaining gas in the cylinder can be determined. It automati- cally sends alerts to the user when the level of gas is low, to order a refill, so that there is no probability of an unexpected shortage and is user-friendly.
- *Automated Shut-Off* : In case of emergencies, this AI-driven mechanism, using a DC motor, cuts off the flow of gas without human interference. This is a very important feature in preventing accidents resulting from leakage because it cuts off the flow of gas as soon as abnormal levels are sensed, adding an important dimension to safety.

B. Hardware Components and Design

➢ *The SLT System Includes Several Critical Hardware Components for Reliable, Continuous Monitoring and Control:*

- *Gas Leakage Detection*: The MQ-6 gas sensor is used for leakage detection in real time. This sensor is sensitive to LPG, butane, and other flammable gases, which means that the system would recognize even minor leaks in good time. Real-time alerts are crucial for timely interventions since they prevent gas accumulation and reduce the risk of explosion.
- *Weight Measurement*: The piezoelectric transducer has high accuracy in measuring the weight of the cylinder. This means that the gas level data remaining will be valid. This device makes users trace their usage over time and will therefore avoid unnecessary exhaustion.
- *Automatic Shut-Off Mechanism*:A DC motor, controlled by AI algorithms, halts gas flow in emergencies by rotating the regulator knob. This mechanism works automatically upon detecting gas leaks or other irregularities, removing the need for user intervention. GSM and Bluetooth Modules: Both modules allow real-time interaction with the SLT application for mobile devices. The module transmits SMS alerts in GSM for emergency alerts, whereas Bluetooth ensures continuous connectivity; that way, users can even monitor gas levels and statuses from their devices.

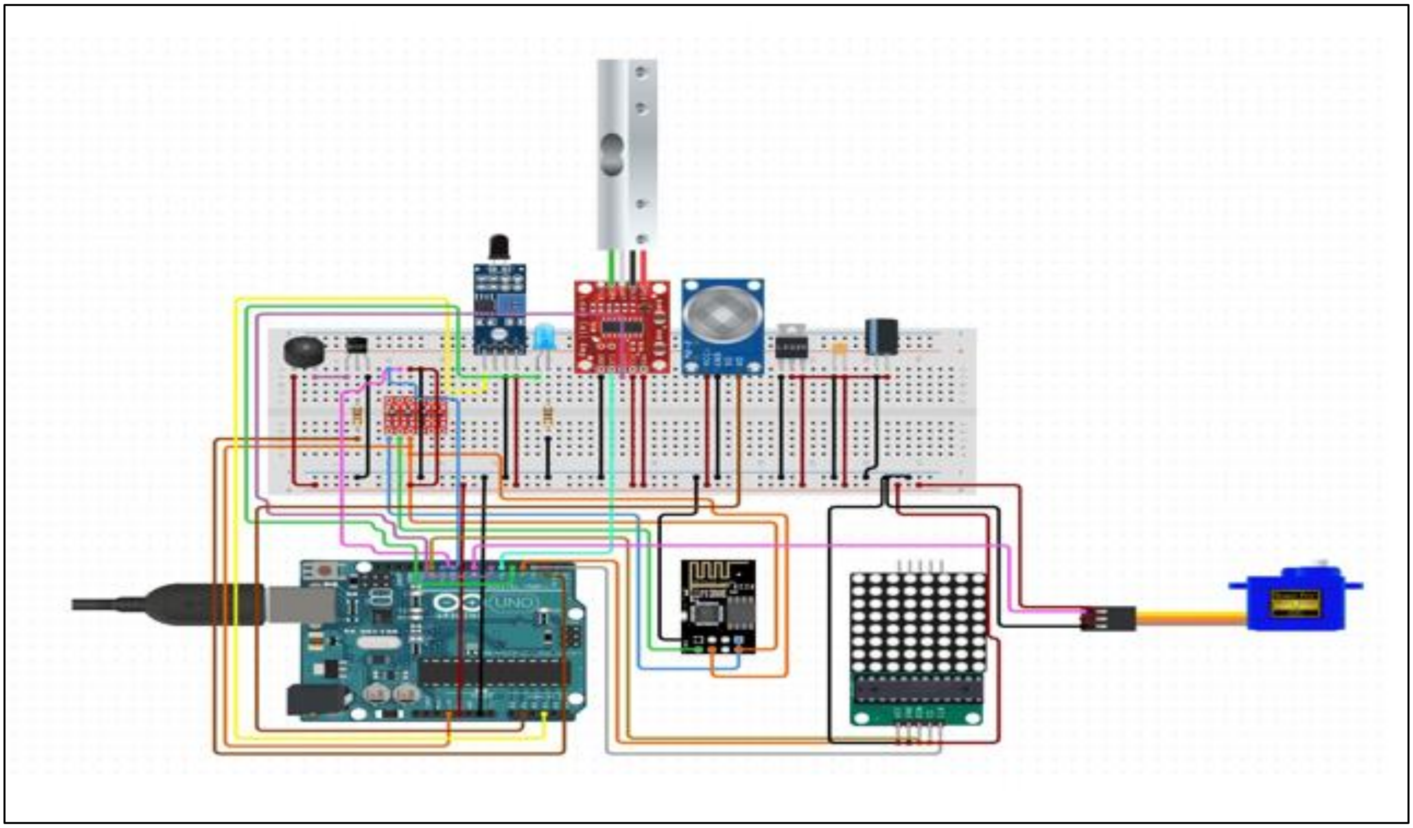

Fig 3: Circuit Dig

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C. Software Architecture

The SLT software stack is built using the MERN framework (MongoDB, Express, React, Node.js), enabling a responsive, feature-rich user interface. The software architecture comprises several essential modules:

- *Data Acquisition Module*: Gathers data from sensors, including gas levels and cylinder weight, in real-time. *Data Analysis and Alerting Module*:The module processes sensor data and initiates alarms in case it detects a gas leak or low gas levels.
- Emergency response is also managed by AI algorithms in this module by initiating the shut-off mechanism.
- *Reporting and Visualization Module*: The mobile application displays usage data, safety alerts, and gas levels in an intuitive format. Users receive insights into their gas consumption patterns, allowing them to optimize their usage.

D. Real-Time Monitoring and Data Collection

The SLT system enables comprehensive, real- time monitoring and data collection, ensuring that users have up-to-the-minute information on their LPG usage and safety status:

- *User Alerts*: Real-time alerts, via SMS or on the mobile application, will be sent to users in the event of a gas leak or when the weight of the cylinder drops below the safe limit. This means that the user will act quickly enough to prevent any hazard.
- *Data Visualization*: The SLT app will provide data in an understandable form. Users can view gas levels, consumption trends, and safety information, thus enabling them to make informed decisions about refilling and usage. This feature enhances user awareness and fosters a proactive approach to LPG management.

E. Automated Emergency Response

In emergencies, the SLT's AI-driven mechanism automatically activates the shutting system. This design protects from accidents because it can't allow uncontrolled release of gas. The actuating process of the closing mechanism includes: Detection of abnormal levels of gases: Once the gas concentration surpasses safe limits, the MQ-6 sensor transmits a signal to the AI module. Engaging the shutdown mechanism: The DC motor immediately shuts off the flow of gas, thereby containing the hazard without any action from the user. Thus, the SLT system is much safer than the conventional configurations because it responds quickly and certainly to leaks.

F. User Interface and Experience

The SLT mobile application is designed with user convenience and accessibility in mind, supporting devices of various types and screen sizes.

➢ *Key Aspects Include:*

- *Responsive Design*: Developed using the MERN stack, the application's layout automatically adjusts to provide an optimal viewing experience on smartphones, tablets, and com- puters.
- *Ease of Navigation*: The app's intuitive interface offers easy access to key features such as real-time monitoring, gas usage history, and emergency notifications. Users can quickly find and respond to critical information.
- *User-Centered Alerts*: Customizable alert options allow users to receive notifications through preferred channels, enhancing engagement and ensur- ing important alerts are not missed.

G. Feature Prioritization

➢ *The SLT Prioritizes Features that Directly Contribute to User Safety and Satisfaction Focusing on:*

- *Leak Detection and Alerts*: Real-time detection of gas leaks, with immediate alerts to the user.
- *Automated Shut- Off Mechanism*: Emergency shut-off capability to prevent gas flow in critical situations.
- *Usage Monitoring and Refilling Alerts*: Continual tracking of gas consumption, with low- weight notifications to remind users to refill on time. These features ensure that the SLT stays focused on safety, user engagement, and operational efficiency.

H. Prototyping and Usability Testing

➢ *The SLT Underwent Rigorous Prototyping and Usability Testing to Ensure Functionality and Ease of Use. The Testing Process Included:*

- *Prototype Development*: Initial prototypes were created us- ing simulated leak scenarios, enabling the development team to refine hardware response times and accuracy.
- *User Feed- back Collection*: The usability tests involved participants who mimicked end-user behaviour. The feedback was collected on the app's navigation, layout, and alerting system to iteratively improve the same based on real-world usage cases. This process of iterative prototyping and testing guarantees that the SLT will meet the user's expectations in terms of reliability, responsiveness, and usability.

I. Future Improvements and Expansion

The SLT system's design allows for future up- grades, expanding its capabilities and enhancing user safety. Planned enhancements include:

- *Insulating Blanket*: Adding an insulating blanket that covers the LPG cylinder could contain potential leaks, providing an extra layer of protection.

- *Full Automation*: Future software updates aim to achieve complete automation, further reducing user intervention and making the SLT a fully autonomous system for household gas management.
- *Smart Home Integra- tion*: Exploring compatibility with smart home platforms (e.g., Amazon Alexa, Google Home) to allow voice control and integration with other household devices, enhancing conve- nience and expanding the SLT's functionality within the home ecosystem.

V. CONCLUSION

The Smart LPG Trolley solution is a notable advancement in the field of managing domestic gas, as it addresses the primary safety issues associated with household LPG usage. SLT integrates IoT and AI technologies to provide a complete solution that prioritizes user safety, efficient gas usage, and ease of operation. The solution incorporates hardware elements such as the MQ-6 gas leak sensor, a piezoelectric transducer for weight measurement, and a DC motor for automatic shut- off. This creates a multi-layered safety framework that detects leaks in real time, monitors gas consumption, and initiates emergency shut-offs when necessary.

The SLT's software architecture, developed using the MERN stack, offers a responsive mobile application interface that keeps users informed and engaged. Through real-time data visualization and alerts, users clearly understand their gas consumption, receive timely reminders for refills, and are instantly alerted in case of a gas leak. This user-friendly app design has been refined through extensive usability testing to ensure that it meets the needs of diverse users and allows intuitive navigation across key features.

The SLT's automated emergency response mechanism, pow- ered by AI, represents a safety innovation for the home, allowing rapid, automatic actions that do not rely on user input. This feature is most important in the reduction of possible hazards associated with gas leaks, improving the overall safety associated with LPG use within the home. The combination of automatic shut-off and real-time alerts serves to both protect users and reduce the likelihood of gas wastage.

Planned future upgrades further strengthen the SLT's po- tential as a market leader in household safety solutions. The addition of an insulating blanket will provide increased safety by containing any gas leaks that may occur and reducing fire hazards. It is targeted to make the SLT fully automated, meaning no manual adjustments will be required, and smarter gas management will be enabled. In addition, integrations with popular smart home platforms, Amazon Alexa and Google Home, are expected to expand the functionality of SLT, enabling users to control gas usage through voice commands while furthering its role within a larger home automation context.

Summary: The SLT is the epitome of a user-centric, technology-driven approach towards LPG safety, being scal- able and adaptable to already existing gaps in the market. Being future-ready with rigorous safety measures, an intuitive interface, and a design that could set a new standard in household LPG management, the SLT will usher in peace of mind as it promotes responsible energy use in homes across the globe.

REFERENCES

[1]. Smith, J., Patel, R. (2023). Integration of IoT and AI in Household Safety Systems. Journal of Emerging Technologies, 15(4), 203-214. Discusses IoT sensor and AI integration for gas leak detection and automation.

[2]. Kumar, A., Lee, T. (2023). Real-Time Monitoring Systems for LPG Safety Using IoT Sensors. International Journal of Smart Systems, 10(2), 115-128. Explores real-time LPG leak detection and gas level monitoring systems.

[3]. Jones, R., Zhang, M. (2024). AI-Driven Safety Mech- anisms in Domestic Gas Systems. Advances in AI and IoT Technologies, 7(1), 72-88. Focuses on AI-driven automated gas shut-off systems for households.

[4]. Nguyen, T., Das, S. (2023). Design and Development of User-Friendly Mobile Interfaces for Smart Home Systems. Human-Centered Design Journal, 9(3), 144-158. Studies mo- bile app interfaces for IoT-based real-time monitoring.

[5]. Miller, P., Shah, H. (2024). Optimization of Gas Man- agement in Smart Homes Using IoT and AI Technologies. IoT Research and Applications, 12(1), 50-65. Discusses predictive monitoring of gas levels and automated notifications.

[6]. Kim, S., Park, J. (2023). Sensor-Based Systems for Gas Leak Detection and Real-Time Alert Generation. Journal of IoT Security, 8(4), 189-202. Analyzes gas leak detection technologies like MQ-6 sensors.

[7]. Hernandez, L., Gupta, A. (2023). Improving Scala- bility of IoT-Based Safety Systems in Multi-Story Buildings. Smart Systems Engineering, 11(2), 101-115. Focuses on ex- tending IoT coverage for larger environments.

[8]. Singh, P., Verma, N. (2024). Enhancing Emergency Response in Smart Homes Through AI-Controlled Shut-Off Mechanisms. AI Innovations Journal, 6(3), 89-105. Explores AI algorithms for emergency gas flow shut-off.

[9]. Chen, W., Rao, K. (2023). Integrating IoT and Mobile App Technologies for Real-Time Safety Monitoring. Journal of Smart Applications, 14(1), 123-138. Investigates mobile app integration for gas leak detection.

[10]. Ali, M., Sanchez, D. (2024). Future Prospects of AI- IoT Integration in Smart Home Ecosystems. Emerging Trends in Technology, 17(2), 65-79. Examines AI-IoT integration for enhancing smart home safety.

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14576735

[11]. Wong, F., Patel, S. (2023). IoT Applications for Gas Leak Detection and Resource Management. Smart Infrastruc- ture Journal, 13(1), 70-84. Discusses dual solutions for leak detection and gas weight monitoring.
[12]. Thomas, R., White, H. (2024). Machine Learning Models for Predictive Gas Consumption Monitoring. AI for IoT Applications, 9(2), 91-108. Explores AI models for track- ing gas consumption and predicting refill needs.
[13]. Santos, L., Park, S. (2023). Automated Gas Safety Systems: A Comparative Study. Journal of Smart Home Technologies, 12(3), 155-170. Compares automated gas safety mechanisms across IoT platforms.
[14]. Nair, V., Kim, Y. (2024). Advances in Real-Time Gas Leak Detection Using IoT and Sensor Networks. International Journal of Sensor Networks, 11(2), 45-60. Focuses on IoT- based multi-sensor frameworks for gas leaks.
[15]. Choi, H., Lin, C. (2023). Enhancing Safety Through AI-Powered Automated Shut-Off Systems. AI and Home Automation, 10(1), 80-93. Examines AI mechanisms for au- tomatically shutting gas flow.