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Smart Gas Cylinder Level and Leakage Monitoring System with Cloud Integration

T Nivethitha,
Assistant Professor,
Electronics and Communication Engineering,
Sri Eshwar College of Engineering,
Coimbatore, Tamilnadu, India
nivethitha.t@sece.ac.in

Sabidharshini P S,
UG Scholar,
Electronics and Communication Engineering,
Sri Eshwar College of Engineering,
Coimbatore, Tamilnadu, India
sabidharshini1252005@gmail.com

K Sobiga,
UG Scholar,
Electronics and Communication Engineering,
Sri Eshwar College of Engineering,
Coimbatore, Tamilnadu, India
sobiga2005@gmail.com.

S Soniya,
UG Scholar,
Electronics and Communication Engineering,
Sri Eshwar College of Engineering,
Coimbatore, Tamilnadu, India
soniyakishore0406@gmail.com.

Suganthi Evangeline,
Associate Professor,
Electronics and Communication Engineering,
Sri Eshwar College of Engineering,
Coimbatore, Tamilnadu, India
suganthi.c@sece.ac.in

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Abstract-- The main cooking fuel used in India is LPG cylinders, and a refill is booked in advance by scheduling a fresh cylinder from an LPG vendor, which arrives in the customer's premises between two to three days. Users find it inconvenient at times when the cylinder runs empty without any prior notice. This poses a critical danger of gas leakage that could lead to hazardous fires and cause heavy damage to people and property. This study proposes an IoT-based Gas Cylinder Level Monitoring System that continues to monitor the level of LPG and detect leakage. This system employs Arduino UNO, NodeMCU, a HX711 load cell amplifier for the measurement of the gas level, gas sensor for leakage detection, buzzer for alarm, and LCD for real-time display. The measured data regarding the level of gas is sent to the ThingSpeak platform in order to remotely monitor it, and also it displays the data on its LCD. If a gas leak is detected, the system automatically sounds an alarm and shuts off the gas regulator to ensure safety.

Keywords: LPG Cylinder, Gas Level Tracking, Internet of Things (IoT), Safety Measures, Leak Detection, HX711 Load cell amplifier.

I. Introduction

Liquefied petroleum gas, known as the mixture of hydrocarbons such as propane, butane, and propene, is one among the most frequently used fuels in India. LPG has been a part of our life since 1860, when it was first becoming a portable fuel; now it is quite extensively used for household cooking purposes and also in industrial processes. As per the report released by the National Statistical Office, about sixty-one percent of Indian houses mainly use LPG as their cooking fuel. Apart from the main composite of LPG cylinders, a small percentage of ethane, ethylene, and a safety odorant called mercaptan is also present in the cylinders to help in leak detection. Most of the households do not track their daily LPG usage properly, and thus they get exhausted at a very unexpected time. This may disrupt the cooking schedule and requires extreme pressure on the supply chain with sudden hikes in demand. Gas cylinders also pose dangers to security as they might leak through broken designs, cracked pipes, or human negligence. A slight spark near a leaking cylinder may result in an unsafe explosion, hence proper safety measures are required [1, 2].

For this system, we would develop an IoT-based Gas Cylinder Level Monitoring System so that we can eliminate the problem of having an unmonitored level of gas in LPG cylinders. The monitoring is carried on continuously, and the LPG level is monitored by measuring the weight through a HX711 load cell amplifier and thus cylinder level. The level being measured with the gas is indicated on an LCD. transmitted to a remote platform like ThingSpeak, for easy web and mobile access. It is displayed on the LCD screen and also transmitted to a remote platform such as ThingSpeak so that it can be accessed through web or mobile devices [3, 4].

The gas leakage sensing is also managed using a gas sensor MQ-6 to calculate the air concentration of LPG. On detection of leakage, it automatically activates a buzzer to create alarm and stops the gas regulator so that no untoward accident happens. The ESP-32 Wi-Fi-enabled microcontroller is used in the system. This is to process and stream data to the cloud real-time monitoring [5]. This is a setup combining parts like Arduino, NodeMCU, a HX711 load cell amplifier, and an MQ-6 gas sensor. The data collected is transmitted to ThingSpeak, which assures proper alerts and continues to monitor it for safety purposes. This system provides timely notifications to prevent accidents and can be beneficial in various fields like communication, automotive, aerospace, and industrial applications [6].

II. Problem Statement

This task specializes in fully monitoring the LPG gas level in a cylinder and detecting any possible fuel leaks. It makes use of a fixed of sensors to get accurate readings, including a HX711 load cell amplifier and an MQ-6 gasoline sensor. The HX711 load cell amplifier checks the load of the gasoline cylinder to parent out how plenty LPG is left, while the MQ-6 sensor identifies any fuel leaks in the surrounding place. All sensors are integrated into a microcontroller system: The Arduino UNO and NodeMCU, which has Wi-Fi, processes the collected data and transmits them. In the local monitoring system, all data regarding the gas level and alerts on leakage are being displayed on the 16x2 LCD screen. Similar data is transmitted to ThingSpeak web platform so that it can be accessed remotely through web and mobile applications [7].

The system uses LEDs to indicate gas level: it gives out a green LED if the gas level is sufficient and a red LED if it is low. Furthermore, after a leakage has occurred, it triggers an alarm buzzer and alerts the user on the cloud [8].

Through this system, additional safety is provided as it can automatically stop using gas when a leakage has occurred.

The system results are presented integrating the hardware components, with the HX711 load cell amplifier -gas sensor-Arduino-NodeMCU-LCD-and ThingSpeak platforms to come up with an all-rounded safety solution while closely monitoring the level in gas LPG cylinders and automatically detecting leaks [9, 10].

III. PROPOSED SYSTEM

This system will incorporate hardware with IoT-based communication, thus accurately tracking the level of gas in the cylinder and then detecting the leakage present inside the cylinder. The below flow diagram further elaborates how the system works, while the block diagram explains the architecture and connectivity in between the main components of the system. As such, both diagrams clarify the functional and design aspect in the system.

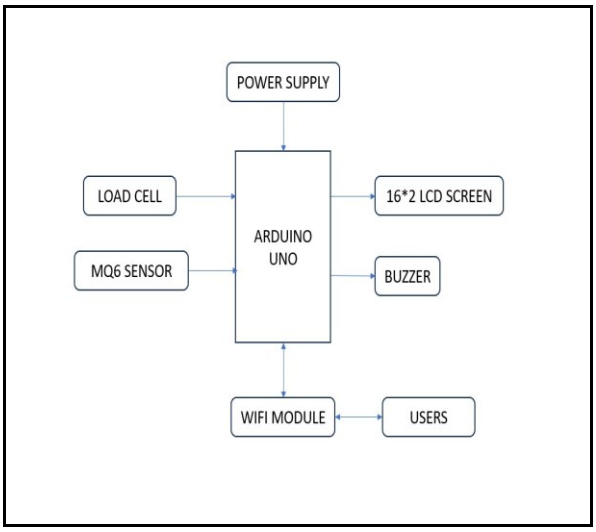

Figure 1: Block Diagram of the Proposed Smart Gas Cylinder Monitoring System

As demonstrated in the block diagram, the whole structure of the Smart Gas Cylinder Monitoring System comprises interconnecting modules. The core lies mainly in the Arduino Uno because it is the main processing unit as it coordinates the operations of all connected modules.

The MQ-6 Gas Sensor detects any leaked gas or fluctuations in gas levels for critical safety monitoring.

The HX711 load cell amplifier is used to measure the weight of the gas cylinder and hence allows one to accurately estimate the remaining gas quantity.

It employs a Buzzer that gives out warning signals through loud beeps in case of abnormal conditions, and a real time through a 16×2 LCD Screen, displaying the gas level, weight, and alert messages for users.

The Wi-Fi Module connects the Arduino UNO to the internet, which transmits gas status updates to the IoT platform ThingSpeak, from which users can access these updates remotely.

The Power Supply runs the whole system, giving uninterrupted operation in case of a power outage.

The consumer can see the status and even receive alarms about the cylinder status in real-time on ThingSpeak or any connected app.

This modular design will ensure seamless hardware and software component communication, thereby providing a reliable and user-friendly gas monitoring solution for the end-users. The system aims to offer safe performance through local alerts through buzzer and LCD as well as remote alerts through IoT integration.

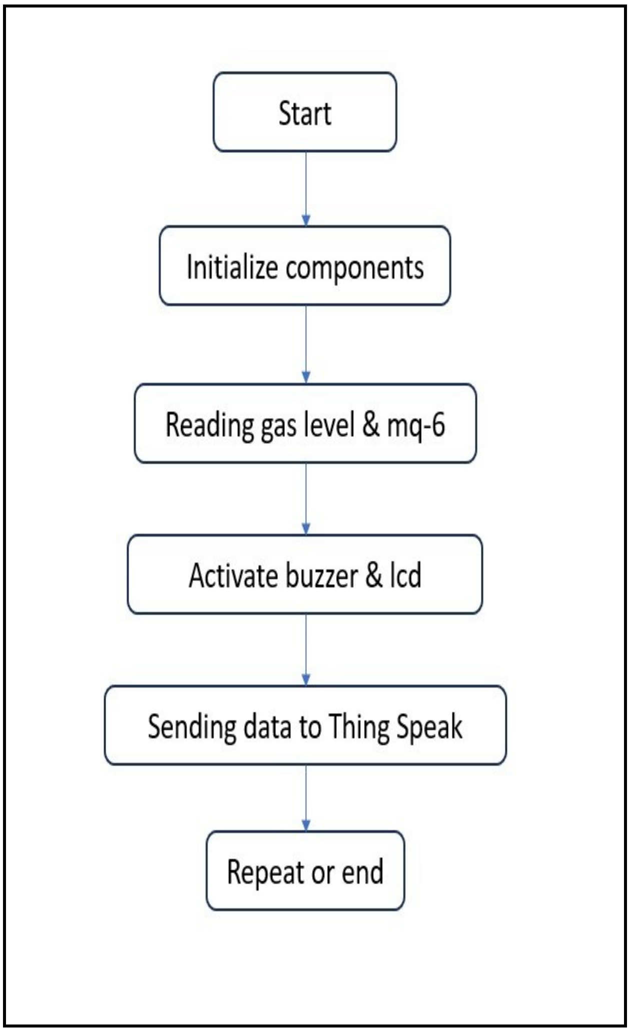

Figure 2: Flow Diagram of the Proposed Smart Gas Cylinder Monitoring System

The flow diagram represents the cycle of operations of the Smart Gas Cylinder Monitoring System. First, the initialization of components is done by activating all the hardware and software systems. The gas levels are continuously monitored through the MQ-6 sensor that senses abnormal gas concentrations, which might indicate a leakage. According to the reading from the sensor, the buzzer and LCD may initiate both audible and visual alerts. At the same time, gas level data is fed to the IoT platform, ThingSpeak so that it can be monitored remotely. The system runs in a continuous loop, thus it constantly monitors and alerts users.
This has demonstrated the description of the proposed system and the sensors are described as follows:

A .NODEMCU

The NodeMCU is the budget open source, microcontroller development board for IoT application. The NodeMCU is based on the ESP8266 chip, which is a 32-bit processor running at 80 MHz with 64 KB of RAM. It also has built-in Wi-Fi, making it ideal for applications that require an internet connection. It also has built-in Wi-Fi, making it ideal for applications that require an internet connection.

The NodeMCU supports Arduino IDE and can be programmed in C/C++ languages and further easily allows integration into different sensors and modules. The Gas Cylinder Level Monitoring System is connected to the NodeMCU, which interfaces with several key components: the load cell through an HX711 amplifier, the MQ-6 gas sensor, an LCD screen, a buzzer, and ThingSpeak for cloud-based data monitoring. In this system, it makes use of 13 GPIO pins of NodeMCU to connect these modules. The HX711 load cell amplifier will especially need two digital pins for data communication in terms of DT and SCK. Similarly, the MQ-6 gas sensor needs an analog pin to detect the gas, and several digital pins to manage the control signals for the LCD.

The NodeMCU has a 3.3V DC supply, which works nicely but can also be powered through USB or an external 5V power source that makes it moveable in different scenarios. The GPIO can also be configured to either digital or analog input or output so that sensors and modules can be interfaced with the system. It has an inbuilt Wi-Fi module, and thus, data from sensors goes to the cloud, where real-time monitoring and alerting is done over ThingSpeak among other such platforms.

B.LOAD CELL SENSOR

TheHX711 load cell amplifier is an electro-mechanical device that measures weight using a strain gauge. It works by detecting changes in its electrical signal when force is applied, either through compression or expansion, which causes the resistance of the strain gauge to change. It functions at 5V DC power supply

.In the Gas Cylinder Level Monitoring System, one side of the load cell is secured to a fixed base, while the other side is connected to the gas cylinder to measure its weight. The HX711 load cell amplifier has four pins: two for power connections (+5V and ground), and the other two transmit the analog output signal. However, the low signal output from the load cell cannot be directly linked to the NodeMCU board. So, HX711 amplifier is used for conditioning purposes and also to readjust the signal to an obtainable value for the microcontroller for its interpretation.

These analog outputs are then sent to the HX711 amplifier, which then sends a digital output through two pins: Serial Clock (SCK) and Serial Data (DATA). The two pins were connected to dedicated GPIO pins on the NodeMCU for easy communication of data that can be read by the system in order to provide an accurate cylinder weight reading. Conditioned data is then processed and presented so the system can track the gas level.

C.MQ6-SENSOR

The MQ-6 is an electronic smoke detector designed to detect traces of Liquefied Petroleum Gas (LPG), iso-butane, and propane in the air. It contains SnO_2, which has low conductivity and high resistance in clean air. It is consisted of SnO_2.

This is done as a measure of analog values, allowing there to be a chance of recording gas concentrations in Parts per Million (PPM). It operates on a 5V DC supply and produces signal in the form of analog and digital: High or Low. Usage The MQ-6 sensor plays the most important role in leak detection of the gas cylinder level monitoring system, alerting once the concentration crosses the safety limit. It connects with an ESP32 microcontroller to allow for the real-time monitoring, therefore, providing more safety and better gas management in homes and industries.

D.ARDUINO

The Arduino UNO is the primary microcontroller of the gas cylinder level monitoring system. The device runs on 5V DC and uses inputs from key sensors like the HX711 load cell amplifier and the MQ-6 gas sensor to monitor the weight of the LPG cylinder and detect any gas leaks.

The Arduino UNO is connected to the HX711 driver, which is used to accurately calculate the weight of the LPG cylinder based on the reading from the load cell. The Arduino UNO will also be provided with information from the MQ-6 sensor looking for the existence of LPG in the air. The execution of programmed logic can aid the Arduino UNO in monitoring levels of gas and raising alarms whenever it identifies a low or leaking level of gas.

The system also uses the Arduino UNO to control an LCD that shows real-time information about the weight of the cylinder and the remaining LPG. Compatibility is added with a buzzer for sounding alert messages and works in coordination with ESP32 microcontroller to upload data to cloud platforms such as ThingSpeak for remote monitoring. This integration only adds to the functionality of the gas cylinder level monitoring system, making it safer, where it, at the right time, shows the necessary notifications and updates from the users.

E.THINGSPEAK:

ThingSpeak is an IoT platform that helps collect, visualize, and analyze data from sensors. In this research, ThingSpeak was used to visualize real-time metrics generated from the gas cylinder level monitoring system. The platform helps track the weight of the LPG cylinder, the remaining LPG percentage, and provides alerts for low levels and gas leakage.

. The ESP32 microcontroller integrates with ThingSpeak and sends the data through its Wi-Fi capabilities. It generates a unique channel for this research, so the ESP32 is authorized to publish metrics by the API of ThingSpeak. It makes the system connect with ThingSpeak, which is properly configured regarding the channel ID and the API key in the program of ESP32.

Once the connection is established, the parameters such as the weight of the LPG cylinder, the percentage of gas remaining, and indicators for low weight (below 5% of the total load) and gas leakage are sent back to ThingSpeak. These parameters are stored in different fields, and thus they can be visualized in real-time using the ThingSpeak web interface, which provides the user with timely updates and enhances the safety measures in monitoring LPG consumption and leak detection.

IV. WORKING OF PROPOSED SYSTEM

The major parameters being sensed are weight concentration level of LPG/butane in the surrounding air. All the sensed data are prominently displayed on the LCD display, two LEDs, web application, as well as the mobile application, all of which are powered through the ESP32 microcontroller.

A wooden frame is used to mount the HX711 load cell amplifier in a stable position that would allow for the measurement. This signal is processed in the HX711 driver circuit to be transmitted to the ESP32 microcontroller through the MISO and MOSI pins for easy recognition of the microcontroller to process it. Concurrently, the output of the MQ-6 gas sensor is connected to the analog output ADC pin of the ESP32 for analysis.

However, for LCD interface, six data transfer pins are used with the ESP32 The red and green LEDs have been assigned two digital pins. A two-channel relay has been assigned to the ESP32 to control a DC geared motor, which in turn controls the LPG cylinder regulator. The system has been designed in such a way that when one relay is activated, this motor adjusts the power supply down from 12V DC to 5V DC for the ESP32 and its sensors

The microcontroller is supplied with 12V DC. The LPG cylinder has a weight of 30 kg with empty weighing 15.8 kg. The cylindrical load is supported by a wooden frame at the bottom, and it carries the weight of approximately 14.2 kg of LPG in it. At critical threshold value 0.71 kg which is equated to 5% of the total load.

The LPG weight is shown on the screen and mobile interface. Green light indicator is provided when the weight goes above 5% or 0.71 kg that means that the level is good; else an alerting red light comes on as the weight goes below this level which indicates that it has become low. Real-time responses from mobile and web applications were given in actual weights and percentage levels, as well as leakage status.

Above 800 PPM, the MQ-6 gas sensor detects leakage in LPG and sends a signal to the ESP32. ESP32 will then activate the relay to shut off the regulator connected to the cylinder's orifice. A message will then be sent to the user via the mobile and web Blynk application that the leak has occurred. Once the PPM falls below 500, this is an indication that the LPG concentration level is safe, and the ESP32 will turn the regulator back on and will continue the monitoring cycle as programmed.

This proposed system has so many safety features to keep users safe. For example, if a gas leakage occurs, then an alarm sound appears, and the regulator stops the gas supply by self-cutting off it for prevention of accidents. At the same time, ThingSpeak sends real-time messages; so a user can take swift actions like refilling a gas cylinder or checking for a leak.

The web application maintains two kinds of user account types-the user, who makes use of LPG cylinders, and the vendor Users can monitor their cylinder's weight and percentage level and request a replacement once their level drops below 5%..The vendor can easily access every user metric and manages their available LPG cylinder stock effectively.

V. RESULTS AND DISCUSSION

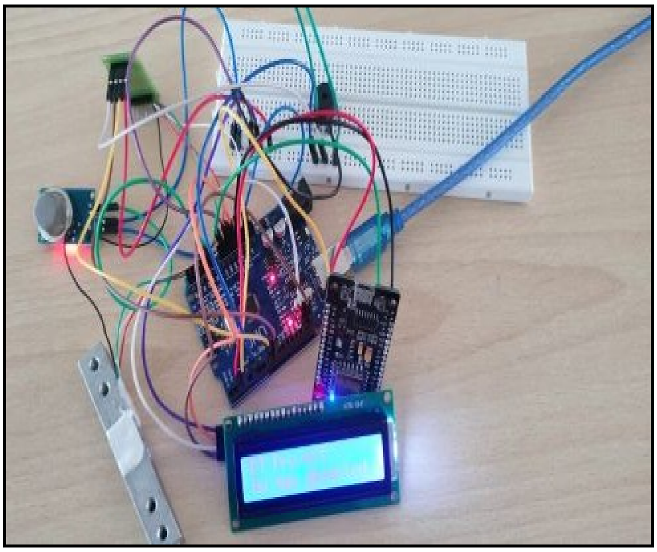

Figure 3: Circuit Diagram Showing the Connections Between Arduino UNO, NodeMCU, and Gas Sensor

The IoT-based Gas Cylinder Level Monitoring System has successfully bridged some of the salient issues in LPG management, specifically in gas level tracking and leak detection. Some critical performance parameters evaluated are accuracy, reliability, and responsiveness, all of which had very promising results in the study.The load cell with the HX711 amplifier was able to determine the weight changes in real-time in an LPG cylinder.

Under testing conditions, it was found that the HX711 load cell amplifier could sense even the slightest depletions in gas weight, thereby giving relatively very accurate information as to how much gas was left over with a percentage error below 2%. Real-time display of such information on LCD and the platform at ThingSpeak allowed keeping track of LPG levels by users and sending alerts for timely warnings whenever their gas level reached below a certain threshold capacity (5%).In addition, LED indicators were highly effective in giving quick, visual alerts with clear indications through red for low gas levels and green for enough gas levels.

The sensor accurately detects the LPG concentration in the air and quickly responded by throwing an alarm as soon as it spots the gas leak. It offered system feedback in terms of analogue output, which enabled direct activation of a sequence of actions in case the LPG exceeded 800 PPM, the safety limit already set. If a leak had been identified, the system would automatically trigger a buzzer alarm and send alerts through ThingSpeak and Blynk so that users' safety and reaction time were maximized. The ESP32-powered relay controlled the activation of a DC geared motor that turned off the gas regulator, thus halting any flow of gas and minimizing the hazardous situation as much as possible.

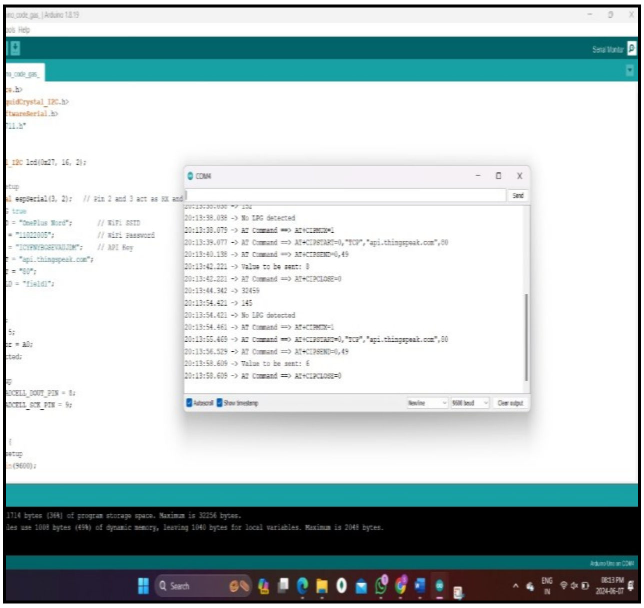

Figure 4: Arduino Serial Monitor Output Showing Real-time Gas Levels and Status

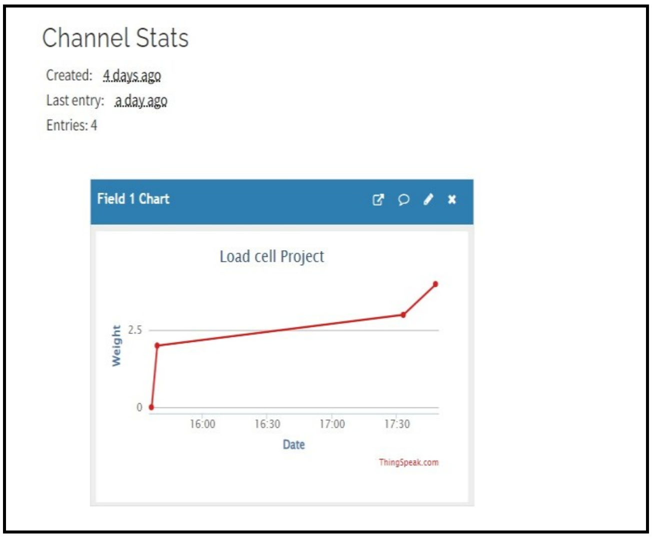

Figure 5 : Think Speak Dashboard Showing Real-time Gas Cylinder Level Data Over Time

This system's integration with ThingSpeak and Blynk enabled this system to give the user information related to gas level and leak via mobile and web applications. This feature was helpful wherever a user is out of the range of the LPG Cylinder, as they will always see real-time updates based on gas levels and any leak events. Due to the cloud-based monitoring, continuous logging data at the website would mean that users could at all times see this historical gas usage patterns and plan refills beforehand, hence providing additional convenience and safety to users.

While the system performed as designed, several areas for improvement existed. First, it was understood that improvement can be done in the accuracy of the HX711 load cell amplifier so that minor changes due to environmental factors, like a change in temperature, may be lessened. Additionally, inclusion of some form of battery backup is needed so the system will continue uninterrupted in case of loss of power. Finally, future work may use machine learning algorithms to predict depletion rates from gas by filling up according to the consumption pattern of users, enabling refill alerts that are even more accurate.

VI. CONCLUSION

This Gas Cylinder Level Monitoring System represents one way in which LPG management can be done by using IoT technology. It constantly detects leaks and gives real-time alerts to the user via a cloud-integrated system. It employs an ESP32 module that allows the system to be effectively integrated with platforms like ThingSpeak and Blynk to enable the remote monitoring of gas levels and, in turn, enable a timely alert regarding the dangers. It checks and controls the gas flow in case of detected leaks immensely increasing consumer safety. The system offers a deployable alternative solution to monitor the consumption of LPG and the dangers associated with leakage are huge issues; real-time monitoring and proactive alerts will make the system more convenient and safe for its user. Possible further updates may include an even more precise HX711 load cell amplifier and predictive analytics applications, and maybe make the system even more valuable for domestic use and even further pushing into the framework of IoT-enabling smart home solutions. The practical and real world application of such an IoT-based system gives a fit testimony to the fact that connected technologies can quite effectively fight real-world safety threats. Such a system encompasses end-to-end solutions that address timely gas management needs while being an exemplary model for other safety-critical applications. In turn, this situates the IoT as a strong critical player in future smart infrastructure, especially areas with continuous monitoring and hazard prevention. In this study, we have discussed the following optimization strategies for the system: One of the ways through which the error related to factors such as temperature variation and humidity shift is minimized through the utilization of load cell accuracy. There are also other options through which we researched that might help utilize machine learning algorithms for prediction patterns of gas usage, aiding the consumer in being on top of their supply without running out of it unannounced.

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