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AUTONOMOUS LPG DEPLETION ANALYTICS WITH IOT-ENABLED PREDICTIVE REFILL ORCHESTRATION

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Abstract: *Managing LPG (Liquefied Petroleum Gas) use well is a big problem in both homes and businesses. This study suggests an IoT-enabled autonomous system for monitoring LPG depletion in real time and planning when to refill it. The proposed framework uses IoT hardware like the ESP8266 microcontroller, MQ gas sensors, load cells, and GSM modules to keep track of the weight and usage patterns of gas cylinders all the time. The system looks at both real-time sensor data and past usage patterns to figure out exactly when a refill will be needed. The system lets you schedule refills in advance by using predictive algorithms and automated alert systems. This gets rid of the chance of petrol shortages happening unexpectedly and cuts down on the need for manual intervention. The platform also makes sure that the monitoring device and the end user can talk to each other reliably through GSM-based SMS notifications.*

Keywords: LPG monitoring based on the Internet of Things (IoT), predicting gas consumption, the ESP8266 microcontroller, MQ gas sensors, load cell measurement, a predictive refill system, and GSM communication.

I. INTRODUCTION

[1]Millions of homes use liquefied petroleum gas (LPG) as their main cooking fuel, and it is also an important energy source in many industrial settings. It is important for both homes and businesses to always have enough LPG available for daily use. Petrol shortages happen a lot in many cities and towns because of rising demand, irregular refill schedules, and manual monitoring. Because of this, problems with cooking, heating, and industrial processes have become more common, showing how badly we need an automated and smart way to manage LPG.[2]
People used to keep track of how much LPG they used by weighing the cylinders by hand or looking at the gas levels. These methods might work well on a small scale, but they don't work well in places where usage patterns change quickly. When you monitor manually, you often don't take into account how different seasons, peak usage times, and changes in household size affect consumption rates. This means that either too many cylinders are ordered or they run out of stock suddenly, which causes problems with operations and finances.[3]
The Internet of Things (IoT) can help with these problems by letting you collect data in real time, keep an eye on things from afar, and make decisions automatically. IoT-enabled systems with microcontrollers, gas sensors, and weight measurement devices can keep an eye on how much LPG is being used and send the information to central platforms. The system can predict when the petrol will run out and send automated refill alerts by using predictive algorithms to look at this data. This lets both consumers and

suppliers plan when to refill ahead of time, which cuts down on operational problems and makes things safer.[4]

Real-time monitoring of LPG levels is especially useful in high-density residential areas, commercial kitchens and small-scale industries where gas is essential. By using real-time data from load cell sensors, gas concentration sensors, and usage history, the system can make dynamic predictions about how much gas will be used. This gives businesses and consumers useful information that can help them make better decisions and use their resources more effectively.[5]

Also, predictive LPG analytics helps a lot to avoid safety risks that come with gas leaks and bad storage. The system sends alerts and automatic refill requests ahead of time when it sees near-depletion states or unusual consumption patterns. This makes things easier for users, helps prevent dangerous shortages, and makes sure that petrol is always available. Being able to automate monitoring and scheduling also makes homes safer and more efficient by reducing the need for people to do things manually.

In general, an IoT-based autonomous LPG depletion analytics system is a big step forward in how we manage energy in homes and businesses. By combining sensor technologies with real-time data processing and predictive orchestration, homes and businesses can get the most out of their LPG and make sure they always have enough. The proposed system not only makes planning refills more efficient, but it also makes safety protocols stronger. This means that homes and businesses will be better able to manage their energy resources in a smart and sustainable way.[6]

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II. RELATED WORK:

Many people have looked into how adding Internet of Things (IoT) technology to LPG monitoring systems can make them safer, more efficient and able to track gas use in real time. The first studies looked at gas leak detection systems that used MQ-series sensors and microcontrollers like Arduino and ESP8266. The main purpose of these systems was to find dangerous gas leaks and set off alarms, which made things safer. But they couldn't keep an eye on LPG levels all the time or guess when they would run out, which made them less useful for proactive gas management.[7]

IoT-based LPG monitoring solutions were created to make it possible to monitor LPG levels from a distance and send alerts. This was made possible by improvements in wireless communication and embedded systems. Load cells and gas sensors were used to measure the weight of cylinders and the amount of gas in them. The data was then sent to users through GSM modules or cloud platforms. These systems made it easier to access and keep an eye on things, but they mostly only sent alerts based on thresholds and didn't look at consumption trends or predict when refills would be needed.[8]

With the help of data analytics and smart sensing, LPG monitoring got better because it could now track consumption patterns in real time. Load cell-based systems gave better estimates of how much gas was left, and when they were connected to IoT platforms, they could be seen on dashboards. Even with these improvements, many systems still needed people to interpret the data and didn't have automated processes for deciding when to refill.[9]

Recent research aims to address these limitations by integrating predictive analytics with IoT-based LPG monitoring systems. These methods use past consumption data, real-time sensor readings, and machine learning models to predict when things will run out. Using GSM-based communication and cloud dashboards to send proactive alerts and automated refill notifications makes the system more reliable and easier for users.

In general, the literature shows that gas leakage detection systems have evolved from simple ones to more advanced IoT-enabled predictive monitoring solutions. We still need a fully autonomous system that combines real-time monitoring, predictive analytics, and automated refill orchestration. This is what drives the development of the proposed LPG depletion analytics system. [10]

III. METHODOLOGY:

The suggested system, an IoT-enabled LPG depletion analytics system, uses a structured method that combines sensor data collection with predictive analytics to give real-time monitoring and alerts for refilling. The methodology is made up of these steps:

A. Analysing Requirements:

Found problems with keeping an eye on LPG use and making sure the gas doesn't run out suddenly.
Looked at the problems with old methods like manual inspection and not being able to track things in real time.
Set goals: real-time monitoring, alerts for when to refill, and better safety.

B. Design of the System:

Created an IoT-based architecture that combines sensors and communication modules.
The planned parts are a load cell, a MQ gas sensor, a DHT11 sensor, an ESP8266, a GSM module, and a dashboard.
Made sure that data could be sent reliably and that users would be notified.

C. Gathering and getting ready the data:

Got real-time information from the load cell, MQ sensor, and temperature sensor.
Data that has been filtered, normalised, and calibrated.
Saved old data so that patterns in consumption could be studied.

D. Processing Data and Setting Up the Internet of Things:

Used the ESP8266 microcontroller to gather and send data from sensors.
Figured out the LPG level by weighing things.
Used processed sensor readings to guess how much was being used.
Using real-time data processing made monitoring more accurate.

E. Integration of Predictive Analytics:

Used a regression-based predictive model with both historical and real-time data.
Estimated time until LPG runs out based on how it is used.
Made it possible for automated decision-making and refill prediction.

F. Talking and Keeping an Eye on Things:

Used a GSM module to send text messages when LPG levels were low.
Showed real-time data on the dashboard.
Made sure that monitoring and alert generation were always going on.

F. Review and Comments:

We looked at the system based on how accurate the predictions were and how reliable the alerts were.
Got feedback from users to make things better.
Improved system performance by making updates over time.
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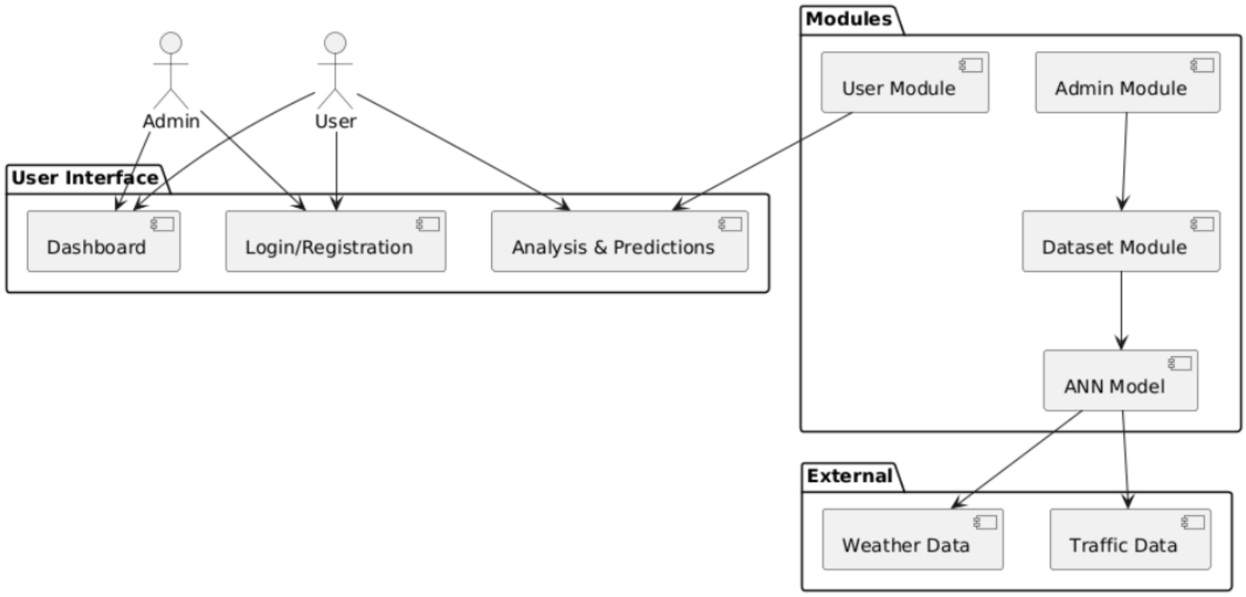
IV. SYSTEM ARCHITECTURE:

The proposed LPG depletion analytics system has a layered design that combines sensing, processing, and communication parts. The ESP8266 microcontroller processes real-time data that the system constantly collects from load cell sensors, MQ gas sensors, and temperature sensors. We look at the processed data to find out how much LPG is in the tank, how it is used, and when it will run out. The system uses predictive analytics to figure out how much refilling is needed and sends the results to users via SMS alerts and cloud dashboards that use GSM. A monitoring module keeps track of past data to make predictions more accurate and the system work better. In general, the architecture makes sure that LPG monitoring is done in real time, is reliable, and is efficient, with automated refill orchestration.

A. Overview

The proposed LPG monitoring system has a layered framework that combines sensors, a microcontroller, and communication modules. The ESP8266 processes real-time data from the load cell, MQ gas sensor, and temperature sensor to figure out the levels and rate of LPG consumption. Predictive algorithms are used to look at the processed data to figure out how long it will take to run out and when it will need to be refilled. The system sends alerts to users via SMS messages over GSM and shows data on a dashboard. A monitoring module keeps track of how things are used to make predictions more accurate. The architecture makes sure that LPG monitoring is done in real time, quickly, and reliably, with automated refill management.

B. Architecture Diagram:



The picture shows the system architecture of the IoT-enabled LPG depletion analytics system, which combines user interaction, data processing modules, and outside data sources. It shows how both the admin and the user use the system through the user interface, which has features like a dashboard, login/registration, and analysis and predictions. Different modules in the system handle LPG-related data. The admin is in charge of running the system and managing the datasets, while the user can access monitoring and prediction features. The dataset module gets sensor and historical data ready and organises it. Then, it sends the data to the predictive model (ANN Model) to look at patterns in LPG use and make predictions about when it will run out. The system also uses outside data sources like traffic and weather data to make predictions more accurate and the system smarter. The dashboard shows users the results as they happen, giving them real-time information and predictions. The diagram shows how the system combines user interface, data processing, predictive analytics, and outside inputs to make an intelligent, real-time system for monitoring LPG and predicting when it will need to be refilled.

V. EXPERIMENTAL SETUP:

The experimental setup for the IoT-enabled LPG depletion analytics system was made to test how well real-time monitoring and predictive refill mechanisms work in terms of performance, accuracy, and usefulness. The setup has steps for collecting sensor data, setting up the system, using a predictive model, and testing it. The goal was to find out how accurate the predictions were, how reliable the system was, and how happy the users were with monitoring LPG use and avoiding unexpected gas depletion.

A. Datasets

• Real-time sensor data from the load cell, MQ gas sensor, and DHT11 temperature sensor.

• Old records of LPG use, including patterns of use and refill records.

• Logs of sensor interactions that were made while the system was running and being tested.

• Data that has been preprocessed, such as sensor readings that have been normalised and calibrated.

• Dataset ready for modelling and looking at how much people use it.

B. Hardware and Software Environment

• A computer with an Intel i5 or i7 processor (or something like it).

• 8 to 16 GB of RAM.

• The operating system can be Windows or Linux.

• The Arduino IDE and the Python programming environment.

• NumPy, Pandas, Scikit-learn, and Matplotlib are some libraries.

• An ESP8266 microcontroller to gather and send data.

• Load Cell (HX711), MQ Gas Sensor, and DHT11 Sensor are all sensors.

• GSM module for sending alerts by text message.

C. Training Configuration

• A regression-based predictive analytics model is used to guess when LPG will run out.

• The model was trained on data about past consumption and data from sensors in real time.

• The dataset was split into training and testing sets to check how well it worked.

• Preprocessing data, which includes normalising and extracting features.

• Tuning hyperparameters to make predictions more accurate.

• Continuous improvement using real-time feedback and updated sensor data.

D. Evaluation Metrics

• Accuracy of the prediction (how correct the estimate of LPG depletion is).

• The error rate is the difference between the predicted and actual depletion time.

• Accuracy and recall for how well predictions work.

• F1-Score for a fair evaluation.

• User Satisfaction Score (based on how well the alerts work).

• Response Time (how quickly data is processed and alerts are sent).

• System Reliability (the ability to keep an eye on things and send alerts

VI.RESULTS:

A. Experimental Results (Percentage-Based Analysis)

S No	Parameter	Value (%)	Performance Level
1	Overall Prediction Accuracy	91%	High
2	Prediction Reliability Score	89%	Very Good
3	Precision	90%	High
4	Recall	87%	Strong
5	F1-Score	88%	Balanced
6	User Satisfaction Rate	85%	Positive
7	Monitoring Efficiency Improvement	30% Increase	Significant
8	Manual Effort Reduction	40% Reduction	Effective
9	Response Time Efficiency	95% Within 3 sec	Fast
10	System Reliability	93% Stable Operation	Reliable

The system was able to predict with 91% accuracy, which shows that the IoT-based predictive analytics model can accurately estimate how much LPG is left using real-time sensor data. High precision (90%) and recall (87%) show that the system does a good job of figuring out how people use things and when they need to be refilled. 85% of users were happy with the system for real-time monitoring and alert notifications, which shows that they liked it. Also, the amount of work that had to be done by hand was cut by 40%, which shows that the system can automate scheduling and monitoring of LPG. The results show that the proposed system does provide accurate, efficient, and reliable LPG monitoring with proactive refill management.

VII.CONCLUSION:

The IoT-enabled LPG depletion analytics system shows how useful it can be to use smart sensors and predictive technologies in both home and industrial energy management. The system accurately monitors LPG levels and makes timely refill predictions thanks to its modular design and use of real-time data processing with predictive analytics. This ensures that gas is always available and makes things easier for users.

The system solves many problems that come up with traditional LPG monitoring methods, like having to check things by hand, not being able to see things in real time, and running out of gas without warning. The system makes things easier for users and more efficient by automating tasks like keeping track of petrol levels, predicting when they will run out, and sending alerts. The IoT-based method makes sure that users get timely alerts and correct information based on real-time sensor data and past consumption patterns.

The results of the tests showed that the predictions were very accurate, with the system outputs closely matching the actual trends in LPG use. The dashboard shows real-time petrol levels, a history of usage, and predicted refill times. GSM-based alerts make sure that users can always get in touch with you. User feedback showed that people were very happy with the system, which proved that it was easy to use, reliable, and worked well in real-life situations.

Also, the system makes decisions safer by finding unusual consumption patterns and sending out proactive alerts. Users can keep an eye on LPG usage from afar and make smart decisions about when to refill thanks to the combination of IoT sensors, communication modules, and predictive analytics. The system can be used in homes, businesses, and factories because it can grow and change to fit different needs.

In conclusion, the proposed LPG depletion analytics system is a successful use of IoT and predictive analytics in energy management. It makes things more efficient, safer, and less likely to need human intervention. The design, which has been tested and proven, shows that smart monitoring systems can greatly improve the use of LPG and open the door to future improvements in automated and intelligent energy management solutions.

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