IoT Based Gas Leak Detection Robot

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***Abstract*—In an era of Industry 4.0 where safety and efficiency are paramount, the development of advanced technologies plays a vital role in ensuring secure environments. One such innovation addressing critical aspects of safety is our IoT-based gas leak detection system. In this report, the development of a device is described that can autonomously navigate in the inspection area with the help of path planning equipped with gas sensors to detect different gases, and this detection system will be connected to a dashboard for various data analysis, real-time monitoring, past records, and studying different behaviors of trends or patterns with the help of machine learning. All this can be accessed through a computer for the user. Also, this device is able to alert the people in the live location where it is inspecting with the help of loud buzzers when any threshold value of gas exceeds. This whole system can also easily be integrated with the existing gas infrastructure, giving it a compatibility factor. Such a robot would reduce human exposure to dangerous environments, improve inspection accuracy and consistency, and facilitate timely maintenance and repairs, ultimately ensuring the integrity and safety of gas infrastructure.**

***Index Terms*—Industry 4.0, Safety, IoT based gas leak detection system, autonomously navigate, Gas Sensors, Dashboard, Real- time monitoring, Alert, Timely maintenance**

I. INTRODUCTION

According to the data given by Gas Authority of Gas, the pipeline network in India is around 24000 km within which about 15000 km is present only in industrial areas. Gas is considered an important source of energy and power. According to the requirements there are different gases used in industries for different applications, for example manufacturing process, power generation, process hearing, etc. Gas pipelines are there- fore considered as crucial asset of industries for several reasons energy supply, cost effectiveness, reliability, environmental benefits, etc. With the increasing use of gases in domestic, industrial, and commercial settings, the need for a reliable and proactive solution to detect gas leaks has become more pronounced than ever. Gas detection systems are critical safety devices used to identify and alert people to the presence of hazardous gases in various environments. These systems utilize advanced sensors to detect gas leaks early, preventing potential disasters such as fires and explosions.

Gas Leakage Inspection Robots are crucial for ensuring the safe operation of gas pipelines, storage facilities, and other infrastructure. Conventional inspection methods often involve human operators who may be exposed to hazardous environments, risking their safety and wellbeing. Additionally, manual inspections can be time consuming, expensive, prone to human error and puts personnel at risk. Therefore, there is a need for an advanced robotic system specifically designed for safety inspections. In some advanced industries, sensors are mounted in the high-risk zone in large quantities which in turn increase the cost of installation. Along with this there is risk on false jamming or alert which creates panic and shutdown of manufacturing process without any actual danger. Since the sensors are mounted in fixed zone which thereby reduce the reliability of the system where the leakage could happen in other parts of pipeline. Also, most of the industries in India do not have sufficient data or any kind of historical data records regarding different parameters, which can help them in various aspects of gas leaks and their infrastructure. In some industries like textile industries the air quality is maintained for efficiency of process but due to leakage this might be affected which in turn would be affected complete plants efficiency with reduction in profits. Thus, there is a need for a specialized robot that can autonomously navigate gas infrastructure, detect potential hazards, and collect accurate data to ensure the safety and integrity of the system.

II. LITERATURE REVIEW

H. Paul [1] explores the application of gas detecting robots in industrial environments, addressing the constraints that are common in the gas distribution sectors. They point out that there are no continuous real-time monitoring systems, no automatic control systems, and no smart gas leak detection systems. They look into a number of models and concepts that could be able to meet these industry standards. Their work focuses on using autonomous gas leak detection and localization to increase safety and efficiency in large-scale industrial settings. They aim to accomplish this in order to lessen operational risks and possible hazards related to gas leaks. The study emphasizes how crucial creative ideas are to supporting safety protocols and streamlining processes in industrial environments.

Mohd Zaki Ghazali [2] is primarily concerned with creating a mobile robot with a microcontroller foundation that is intended to detect gas leaks during transit. They talk about how the robot can move more easily and precisely by using ultrasonic sensors, which allow it to navigate and control its back-and-forth mobility. They suggest that a variety of businesses will be significantly impacted by this technology. Enhancing workplace safety standards and environmental monitoring efforts can be greatly boosted by enabling the safe and effective detection of gas leaks. This study highlights the value of creative approaches to solving pressing problems pertaining to gas leak detection, which has broad implications for both business and environmental preservation initiatives.

Samuel Soldan [3] investigates a technology that promises to boost industrial gas leak detection procedures' effectiveness, lower operational risks, and increase safety. They draw attention to the noteworthy consequences of the novel approach for environmental monitoring and industrial safety. It has the ability to lessen the effects of gas leak accidents on the environment and public health by providing a proactive way to handle them. This technology has the potential to completely change how gas leaks are found and handled in large industrial settings. It is a promising advancement in the domains of robotics and industrial safety. Additionally, they talk about how to use various sensing devices, like IR thermographic imaging and Tunable Diode Laser Absorption Spectroscopy (TDLAS) measurement systems, to find leaks in pipes and spills of liquid on the ground. In the end, this multifaceted strategy could lead to safer industrial operations and environmental stewardship by improving detection accuracy and guaranteeing prompt reaction to gas leak situations.

Sujiwa [4] explores the measurement analysis of MQ-6 LPG gas leak detecting systems, focusing on distance variables in particular. Their study aims to collect information on the sensor's accuracy, sensitivity, and response time at different testing distances. They hope to offer important insights into the performance characteristics of MQ-6 gas leak detecting devices under various distance settings by carrying out in- depth analyses of these crucial aspects. By providing useful information for maximizing the device's deployment in real- world applications, this research advances our understanding of the device's capabilities and limitations.

III. PROJECT OVERVIEW

The proposed gas leak detection system employs an autonomous robot equipped with MQ sensors for continuous real-time monitoring and quick response to gas leaks. For navigational support, it also incorporates additional sensors such as an accelerometer and ultrasonic. The system sends data to a cloud server for monitoring and alerts, enhancing overall safety and efficiency.

Fig. 1. Gas leak detection robot

There are many uses for the IoT based gas leak detection system, which guarantees security and safety in the commercial, industrial, and residential domains. It can keep an eye out for gas leaks in commercial and industrial buildings and guarantees the safety by monitoring gas pipelines. The technology can also be used by government agencies to audit pollution levels and check for leaks. Deployment in thermal power plants also helps to minimize downtime and improve reliability by facilitating real-time data collecting.

IV. WORKING OF SYSTEM

A robot, powered by a 12V battery, is designed with four wheels for mobility and flexibility in navigating diverse terrain within industrial facilities. Four MQ sensors are strategically mounted on the top of the robot, covering all sides, and enabling comprehensive gas detection capabilities. These sensors can be interchanged to detect various gases commonly found in industrial settings, offering versatility and adaptability to different detection requirements. To ensure systematic coverage of the industrial area, the robot is programmed with predefined coordinates using Arduino code, defining its path of traversal. This path planning approach enables efficient and thorough monitoring of the entire facility, enhancing the detection and localization of gas leaks. For large-scale industrial facilities, the system offers scalability by enabling the deployment of multiple robots simultaneously, thereby enhancing coverage and detection efficiency.

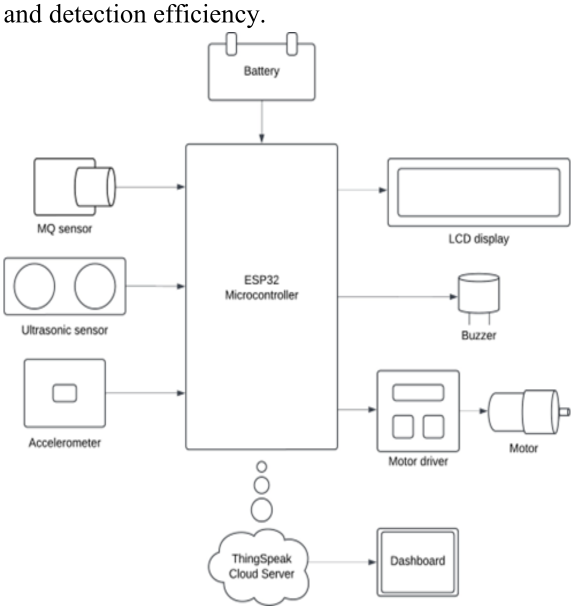

Fig. 2. Block diagram

As the robot travels the predefined path, the MQ sensors continuously collect PPM values of gases present in the surrounding environment. These values are transmitted to an ESP32 microcontroller on-board the robot, serving as the central processing unit for data acquisition and transmission. The microcontroller then sends the gas sensor data to both a local display on-board the robot and to a central dashboard via a common Wi-Fi connection, enabling real-time monitoring and analysis of gas concentrations. Upon receiving the gas sensor data, the central dashboard will display various data in different forms, and it also employs machine learning algorithms to analyze the PPM values and determines the state of current environmental conditions. Threshold levels are predefined based on safety standards and regulatory guidelines, allowing for timely detection and alerting of gas leak incidents. Furthermore, all collected sensor data, including gas PPM values and robot telemetry data, are stored for further analysis, aiding in maintenance efforts and risk mitigation strategies.

Fig. 3. Architecture of gas leak detection system

In addition to gas detection capabilities, the system is equipped with various safety features and sensors to enhance overall operational safety and efficiency. These include an ultrasonic sensor for obstacle detection, a buzzer for audible alerts in case of gas leaks or safety hazards, an accelerometer for fall detection, and a voltage regulator for stable power supply to all on-board components.

V. USER INTERFACE

The dashboard design is made up of HTML, CSS, and JavaScript. It is connected to the ThingSpeak cloud server platform where our data is stored. This dashboard consists of following options:

1) View Tracking: To view the live and continuous data readings of gas sensors with alert signals
2) Tabular Data: To view the historical data in tabular form
3) Graphical View: To view the continuous data in graphical form with respect to time and ppm value
4) Environment Condition: To view the present state of the working environment for gas infrastructure using Machine Learning (ML) in terms of value 0 (Safe) and 1 (Unsafe).

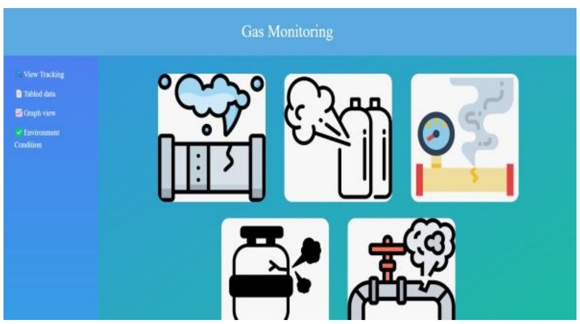

Fig. 4. Dashboard

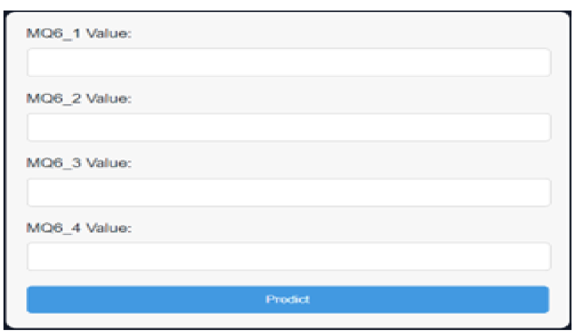

Fig. 5. Current condition analysis using ML

We have used a random forest algorithm for machine learning, which belongs to the supervised learning technique and uses 80 percent trained dataset and 20 percent test dataset. The basic idea behind the algorithm is to combine multiple decision trees in determining the final output. The output from various sensors is aggregated and based on the dataset the final output in the form of 0 and 1.

VI. RESULTS

These are the result after successful testing of gas leak detection system it gave the graphical representation of the gas leakages and ppm amounts of gases in different environment.

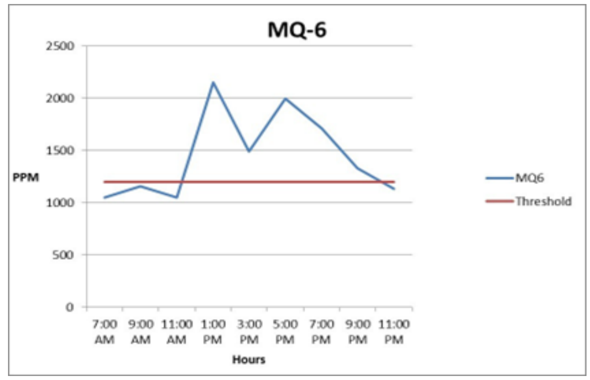

Fig. 6. MQ6 results

The above graph was obtained by spraying butane gas using Butane can sprayer over a certain period following a specific
pattern. As the butane gas spray, amount was increased sudden rise of gas in environment was detected. The normal value of ppm was around 1100 ppm and after spray the rise in ppm was witness around 1800 ppm.

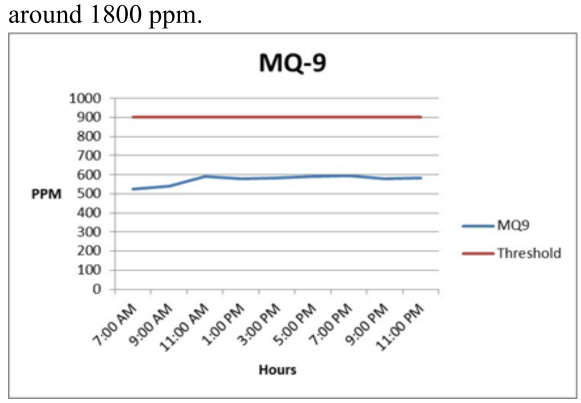

Fig. 7. MQ9 results

This detection was made near the LPG pipes in building to check or detect any potential leaks. The amount of LPG gas over a certain period of time was almost constant which states that there is no leakage in the pipes therefore it could be used to maintain the safety and integrity of system.

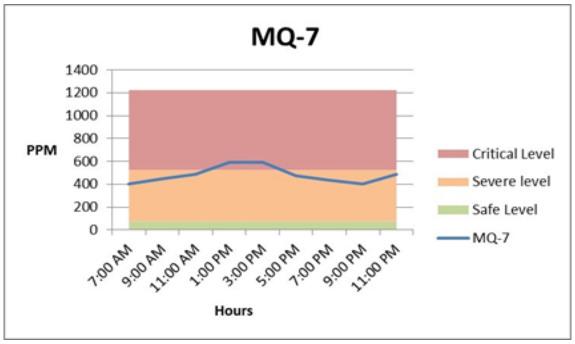

Fig. 8. MQ7 results

To obtain the above result the system was made to stand near traffic signal and by side road to collect the data. The result showcases the amount of Carbon monoxide is more than the actual amount which a human could consumed.

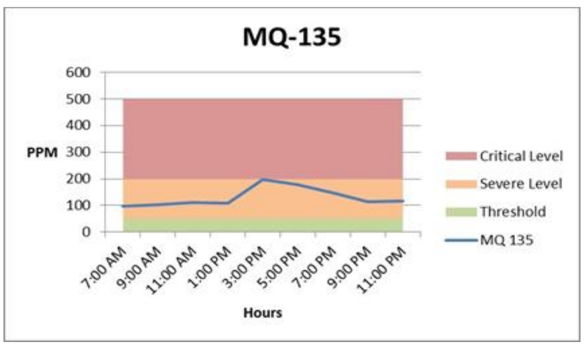

Fig. 9. MQ135 results

This result was obtained to know the air quality of environment to check the pollution levels around operating area. The system was kept outdoor to collect the data over a compete day. The result depicted pollution level increase from morning to midday to peak hours which shows the when should we focus to reduce the pollution levels.

VII. CONCLUSION

We have developed a gas leak detection system that operates autonomously within gas infrastructure environments, effectively identifying potential hazards and transmitting data to the ThingSpeak platform for real-time monitoring. By leveraging IoT technology and machine learning algorithms, our system enhances situational awareness and enable analysis to determine whether an environment is safe or unsafe. We have monitored different gases using MQ sensors, providing valuable insights into environmental conditions. Through these capabilities, our system has the potential to significantly contribute to the creation of safer and more sustainable environment. By proactively identifying and addressing gas leaks, our system aims to mitigate risks and safeguard lives and property, ultimately fostering a healthier and more secure environment.

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