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Original Article

IoT Based Smart Monitoring and Controlling System for Gas Leakage in Industries

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Abstract *- The main objective of the work is to design a microcontroller-based toxic gas detecting and alerting system. The ultrasonic sensor is used to determine if gas is present in the ambient or not by analyzing the acoustic waves. The MQ-135 gas sensor is used to identify the leakage of gas. The IoT part of the system deals with the connectivity of the entire system to the Blynk platform via the Wi-Fi module of the NodeMCU microcontroller.*

The emergency actions are automated, and detection is predicted using two preset threshold values of gas pressure in case of gas leakage. The system enables monitoring and alerting gas leakages in industries before the accident could occur, leading to a faster response time in the event of a leakage condition. The availability of the Blynk cloud platform makes it easier to collect regular data and generate useful insights from it. The results from the accumulated data of the ultrasonic sensor let us automate security actions before the conditions go out of control.

An IoT - based smart control and monitoring system for industrial gas leakage problems is proposed with the ability to monitor the pipelines, store the pressure levels and generate insights based on recorded data. The key idea of the system is to generate notifications and alarms based on the preset threshold value to show an increase in safety. The IoT part of the system deals with the connectivity of the entire system to the Blynk platform via the Wi-Fi module of the NodeMCU microcontroller. The online platform provides a range of tasks that can be done. From data visualization to automation, Blynk provides multiple facilities to carry out our essential operations in the project. As a part of our system, the online platform helps us to read, record, and analyze the data received from the microcontroller unit. The e-mail notification is also initiated through this online mobile application.

Keywords *- Automated action, Alert Notifications, Blynk Cloud platform, Gas Leakage, Smart Control System.*

1. Introduction

Gases are important in most industrial processes like catalysts, fuels, or raw materials. These gases can be very lethal when mishandled. Leakage is always a serious problem when gases are used. Maintaining gas pipelines and storage devices is a crucial role in all industries. Gas leakage accidents from history tell us how severe the effects of exposure can be. The Bhopal Gas Tragedy and Vishakhapatnam Gas Leak are two major accidents that created great chaos.

The rise of connectivity methods like Bluetooth, Wi-Fi, and many such wireless sensor methods facilitated the industries by improving the control systems' time, speed and accuracy. This paper proposes an IoT- based smart control and monitoring system for industrial gas leakage problems with the ability to monitor the pipelines, store the pressure levels and generate insights based on recorded data. The key idea of the system is to generate notifications and alarms based on the preset threshold value to show increases in safety.

The system also features automated quick e-mail notifications, an alarm, and an indicator when the leakage has occurred. Within a certain period, the doors are also closed to prevent the spread of the gas. The door is still made to be manually accessible.

2. Literature Survey

Industrial IoT has eased the problems they've been facing with the availability of smart connectivity and automation of treacherous tasks. Industrial gas leakage is one of those complex tasks that must be handled. Manual methods are already being replaced. This section mentions the recent methods introduced to meet the existing challenges.

Afsana Mim Anika, Ms. Nasrin Akter Md., Niamul Hasan, Jannatul Ferdous Shoma, Abdus Sattar - "Gas Leakage with Auto Ventilation and Smart Management System" [1] A smart management system for gas spillage-the supervisor is notified through SMS and Blynk application. It can detect fire; gas and does the necessary to reduce the gas density by auto air ventilation and extinguish the fire by spraying water. The results show increased safety, reduced death toll, and rand the damages that occur to the surrounding.

Soumya Debashis Das, Kazi Jabed Akram, Gyan Ranjan Biswal, Tarikul Islam "A High Precision Cost-Effective Ultrasonic sensor for detecting gas leakage in gas insulated switchgear" [5] The system detects gas density using acoustic signals and found suitable due to the electrical properties in ideal gases. The technique detects gas leakage at ppm level, and the live conductors and other electrical equipment inside the GIS are surrounded by SF*6* gas. The ultrasonic sensor's performance has been calculated by considering parameters such as pressure, temperature, molar mass, and humidity. The simple design is still able to provide effective results

Sourav Debnath, Samin Ahmed, Suprio Das, Abdullah-AI Nahid, Anupam Kumar Bairagai, "IOT based low-cost gas leakage, fire and temperature detection system with call facilities" [6] Another system with low-cost devices designed to make calls to the customer using GSM connectivity whenever accidental leakage or smoke occurs. It sends data to the alarm, alerting the users and sending a graphical alert to the server with another unit. A temperature sensor is included to detect the temperature of that hazardous situation. Certain ML algorithms are used to predict the chances of accidents in advance based on data from different sources.

Joao B. A. Gomes, Joel J. P. C. Rodrigues, Ricardo A. L. Rabelo, Neeraj Kumar, Sergey Kozlov, "IOT-enabled gas sensors: Technologies, application, and opportunities" [4] This system analyses the performance of transducers and their efficiency with IoT enabled systems. It looks to simplify the data gathering and sharing processes, giving users better real-time results. The efficiency of wireless-based solutions for ambient gas monitoring is deduced and discussed.

Haythem Ahmad, Bany Salameh, Senior Member, IEEE, Mohammad Fozi Dhainat and Elhadj Benkhelifa, "An end-to-end early warning system based on wireless sensor network for gas leakage detection in Industrial facilities," [2] This system presents an integrated end-to-end wireless sensor network, fully making use of the IoT functionalities and capabilities in WSNs at the network level. Data acquired from the various experiments are used to analyze the reliable performance of the implemented system of robustness and reliability of data delivery.

Xiaolin Liu, Chun Hu, Peng Peng, Rui Li, Xiaoming Zhao, Dezhi Zheng, "In-pipe detection system based on magnetic flux leakage and eddy current detection" [8] The in-pipe detection system based on magnetic flux leakage and eddy current detection takes the magnetic flux leakage and eddy current detection as the main detection parameters, with detection sensors, data collection, and storage system. Different types of defects are identified, and the Data is validated.

Quan Lu, Qin LI, Likun Hu, Lifeng Huang, "An effective low contrast SF6 gas leakage detection method for infrared imaging" [7] It is an online infrared imaging detection method for SF6 gas leakage using a Gaussian mixture model. In the initial stages, the random noise in the image is suppressed. Contrast limited adaptive histogram equalization is used to enhance the dark details of the infrared image. Then, an improved Gaussian mixture background model is applied to adaptively segment the SF6 gas leakage and note the leakage area. The results of the experimental conditions proved to highlight infrared imaging to be effective over conventional methods.

Hilton Paul, Mohammad Khalid Saifullah, Md. MonirulKabir, "A smart natural gas leakage detection and control system for gas distribution Robotics" [3] Smart natural gas leakage detection and control system are implemented in software and hardware modules for natural gas leakage control from remote places. The model can quickly detect natural gas leakage by continuous monitoring and can control gas leakage by a smartphone from any place. The system works effectively with natural gas monitoring, and the effects of greenhouse gases can be reduced to a great extent.

Yi Yang "Design of a Multi-Sensor Ultrasonic Detection System for SF6 Gas Leak in Power Systems" [10] The model is based on an ultrasonic gas leakage system with multiple sensors for optimization. The system can be effectively used for active gas leakage monitoring, and the strength of the signals can be used to determine the pressure level through the pipelines. The calculation results lead to expected results and can be used to implement other such systems.

Yahaya S. Z., M. N. MohdZailani, Z. H. CheSoh, K. A.Ahmad [9] The major concern of IoT Based System for Monitoring and Control of Gas Leakingare **Gas** leakage and fire accidents. Using the integrated advantage of technology, fire accident is reduced. The system proposed focuses mainly on LPG gas. With NodeMCU as the controller of this system, it works on the gas level and flame occurrence from MQ-2

sensors and Flame sensors, respectively. Based on the leakage event, instant decisions are supposed to be made. When there is any occurrence or sign of leakage, the sensor notices it and transmits the information quickly to be processed. As a result of the signal obtained from the sensor, the controller activates the predefined actions that reduce the spread of the gases to the environment. This method is the easiest implementation of IoT and gas detection in real-world applications. It signifies the strength and speed of IoT-based control systems. The performance of the sensors is also calculated as a concern to show accuracy, speed, and proper response.

3. Methodology

3.1. Proposed System

3.1.1. The Early Warning System

The pre-existing systems have effective results the for the design purpose. The key idea introduced in this paper is a method to analyze gas leakage's chances before it occurs. For this, we record the continuous pressure of the gas through the pipeline and the container. Based on the properties of the gas, a normal or generalized flow rate(pressure) is defined. A variation in the normal values could go higher or lower due to major or minor changes that may be easily detected or, in some cases, be very difficult to find. The causes could be unpredictable in many cases. So, when a change is detected in the valve, the inlet flow rate must be brought under control or reduced. As a first step, this is checked. Usually, the chances of failures occurring at this are less unless the external or internal factors of the pipeline are affected. Multiple factors could affect the flow, like the material used, the pipe's physical properties, the reactivity of the pipe with the gas, etc. Similarly, physical factors like room temperature, pipeline temperature, and room pressure are also considered as they could result in significant changes to the normal flow rate.

Based on the circumstances that could lead to a chance of leakage, an early warning system is included as a part of the system. Its major task is to generate a mild alarm, send a notification to the user, and reach out to the workers for manual system checking. So, when the pressure measured by using the ultrasonic sensor is above or below the defined rate, an instant an alert is created to notify people on and off-site. Mostly the issue would be something simple that can be easily rectified, but when the issue is something big, the next level of safety has to be introduced immediately.

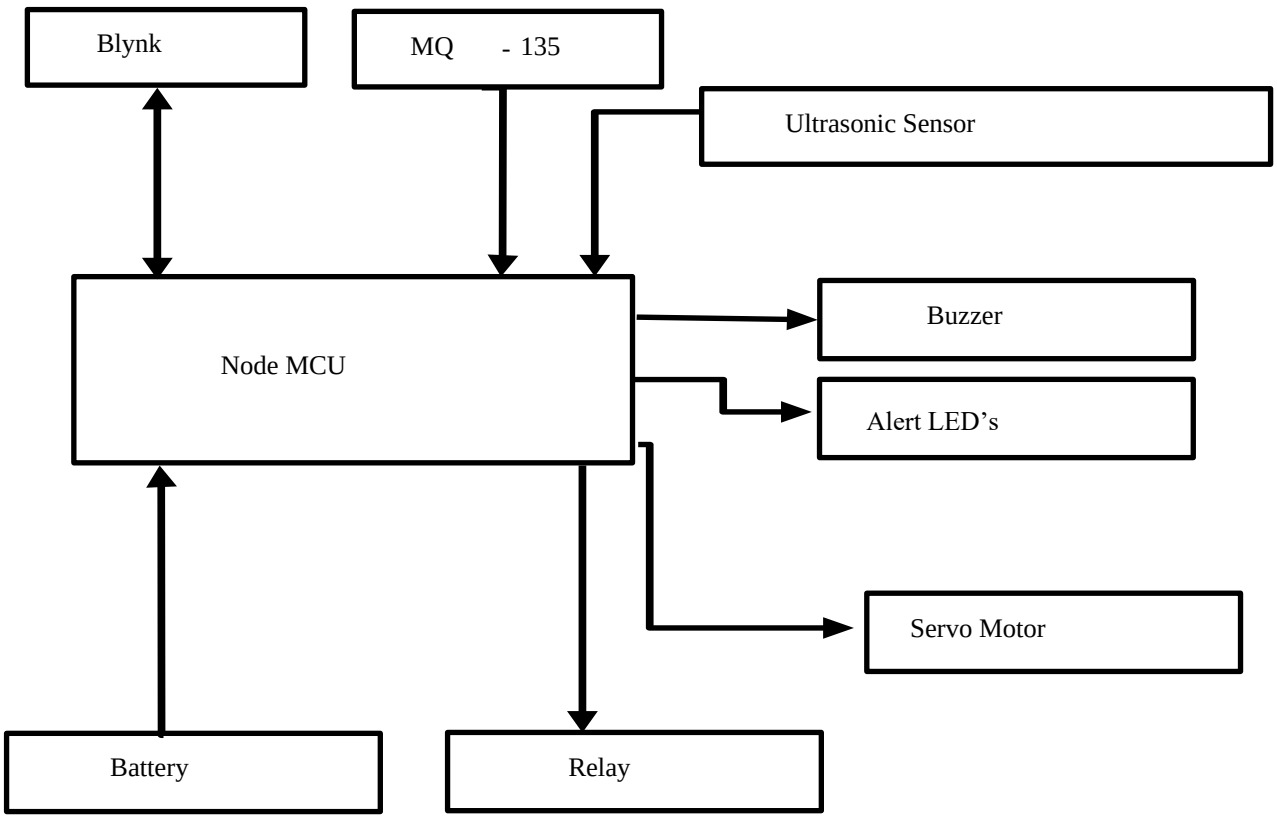

Fig. 1 Conceptual diagram for the proposed system

3.2. Working of Ultrasonic Sensor

Sound propagates differently based on the medium of propagation. In gases, the ultrasonic speed is an activity of the temperature, pressure, humidity, and gas mixture properties. With the support of these characteristics, acoustic waves can be used to determine if gas is present in the ambient or not. The gases can be analyzed by the speed of the sound, the attenuation of the signal, the acoustic impedance, or the combination of these characteristics.

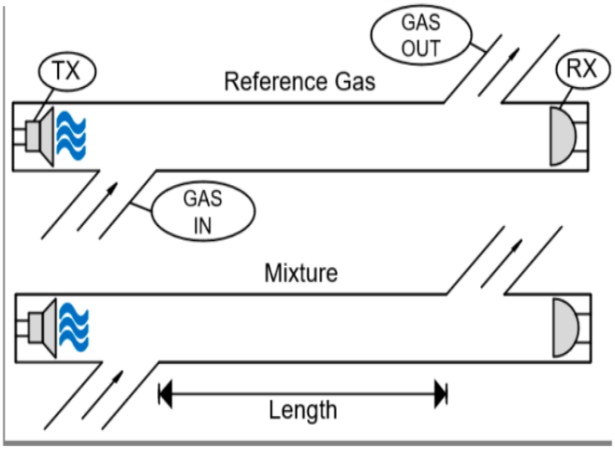

Fig. 2 Acoustic Sensor

The most used and studied technique is based on the difference in sonic velocity in different propagation mediums, using the propagation time at a fixed distance to determine the composition of a given gas mixture. Equation (1) shows the dependency of the sound speed on the gaseous propagation medium.

$$c = \sqrt{(\frac{kRT}{M})} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where c is the velocity of the sound, in meters per second; k is the average specific heat ratio; R is the gas constant; T is the temperature, in kelvin; and M is the average molecular weight. The attenuation of the acoustic signal describes how much energy is scattered at a defined propagation distance.

Here, The equilibrium of the gases isn't maintained, and the molecules exchange energy by collisions, generating thermal energy. The energy generated is proportional to the energy monopolized by the gaseous molecules creating the movement that leads to the collisions. It is said that the system absorbs the acoustic energy, and the absorption level is proportional to the concentration of the gases that formulate the propagation medium. The attenuation of the signal is calculated using Equation (2), where Po and P are the acoustic pressure at two different points, α is the attenuation coefficient, and X is the distance from Po to P.

$$P = Po\, e^{-\alpha X} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Acoustic impedance analysis is a less popular technique for sensing gases, and no commercial uses of this technique have been identified. Where Z is the acoustic impedance, ρ is the gas density, and c is the sonic speed. This technique generates detection errors, as a given gas mixture can be mistaken for another, as they can present the same density. It may be used within another detection technique.

$$Z = \rho c \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

The use of ultrasonic speed, acoustic impedance, and attenuation in the air or other gases could decrease the energy consumption of the sensors when using this technique, as well as be more precise, considering the fact that the reference chamber could suffer variations by contrast with the environmental changes in the ambient where the system is installed.

3.3. The Leakage Detection System

As depicted in the diagram, the second part of the system deals with detecting the gas if there is any leakage. The MQ-135 gas sensor is used in this system. It can sense gases like NH3, NOx (x=1,2…n), CO2, Alcohol, Benzene, and Smoke. For this paper, we closely work with CO2 and Smoke. These sensors are placed in a continuous location at fixed distances surrounding the pipe. When leakage is detected, the gas supply has to be immediately cut, and the gas storage chamber is also automatically safeguarded with an extra layer around its surface. Then, the controller activates the necessary operations to be taken. The emergency actions are high-level alarms with a buzzer and immediate mail to respective departments to bring in control. The last action is to close the door automatically after a certain period to prevent the extra gas spread. The door is still manually accessible, so introduce manual backup too. Later, the leaked gas can be directed to a safety chamber.

3.4. Working Of MQ-135 Sensor

The MQ-135 Gas sensor can detect gases like Ammonia (NH_3), sulfur (S), Benzene (C_6H_6), CO_2, and other harmful gases and smoke. This sensor also has a digital and analog output pin similar to other MQ series gas sensors. The digital pin goes high when the level of these gases goes beyond a threshold limit in the air. By using the onboard potentiometer, this threshold value can be set. The analog output pin outputs an analog voltage which can be used to approximate the level of these atmospheric gases. The MQ135 air quality sensor module works at 5V and consumes around 150mA. For accurate results, it requires some pre-heating before it can give.

3.5. The IoT Integrated System

The IoT part of the system deals with the connectivity of the entire system to the Blynk platform via the Wi-Fi module of the NodeMCU microcontroller. The online platform provides a range of tasks that can be done. From data visualization to automation, Blynk provides multiple

facilities to carry out our essential operations in the project. As a part of our system, the online platform helps us to read, record, and analyze the data received from the microcontroller unit. The e-mail notification is also initiated through this online mobile application. Now, the integrated system will generate integrated results for the necessary conditions the microcontroller has been programmed for. Without any defect with the pipeline or gas storage chamber, the data can be very smoothly monitored and displayed as a 2D /3D graph. In case of any issue that arises, the Blynk application carries out the preset actions.

3.6. System Components

3.6.1. Arduino IDE

The Arduino IDE is an open-source software used to write and upload code to the Arduino boards. In this system, the code uploaded to the NodeMCU is compiled and debugged using Arduino.

3.6.2. Blynk

Blynk was specially designed for the Internet of Things applications. It is used to control hardware at a long distance and to display sensor data. It has been used to store data, visualize it, and do many other operations like e-mail forwarding.

3.7. Hardware Components

3.7.1. NodeMCU

Node MCU is an open-source firmware for which open-source prototyping board designs are available. The proposed system is an intermediate platform between the sensors, actuators, and the cloud platform for processing the raw data and generating outputs. The Wi-Fi module provides connectivity. It has 17 GPIO pins(11 are Digital I/O pins), out of which one pin is an analog pin, 4 pins support PWM, 2 pairs are for UART(UART0 and UART1), and supports 1x SPI and 1x I2C protocol.

3.7.2. Relay Module

The relay module controls the high voltage and high current loads such as motors, solenoid valves, lamps, and other AC loads. Here, the external actuators require relay modules.

3.7.3. Servo Motor

Servo motors can roll approximately 180 degrees (90 in each direction) and operate like standard but smaller. The automated door requires servo motors to work as per the conditions.

3.7.4. Buzzer

A buzzer or beeper is an audio signaling device with different working principles. The use of buzzers in this system is to warn people in case of leakage.

3.7.5. LEDs, PCB Board and Connecting Wires

These are the very basic components required to carry out the preliminary actions. The LEDs are used as indicators for the system. The PCB board eases connections while using wires.

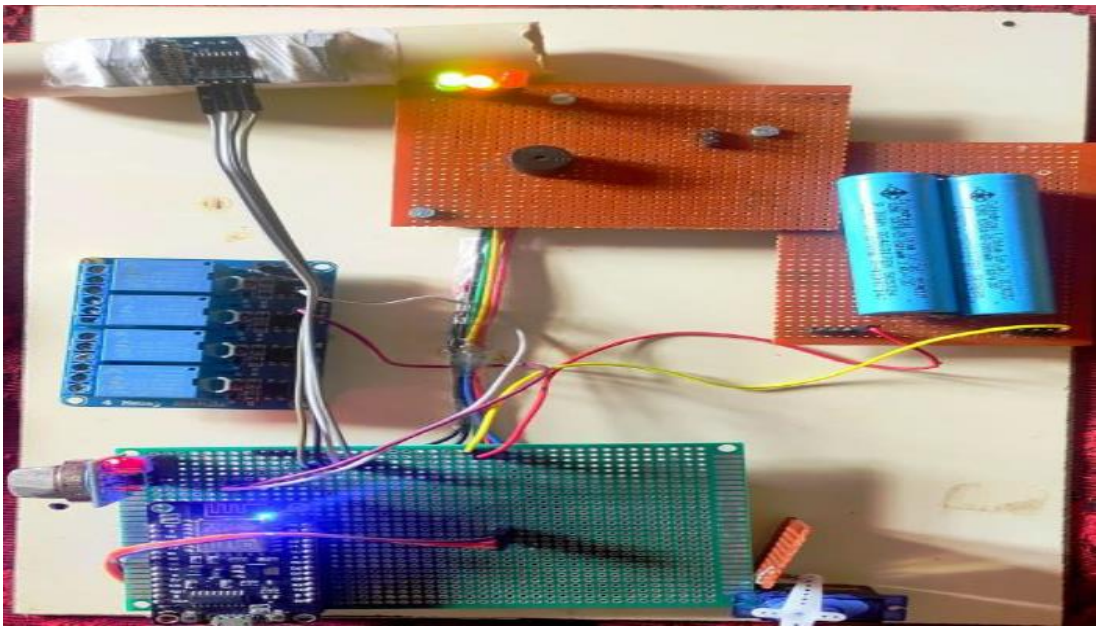

Fig. 3 Developed Working Model

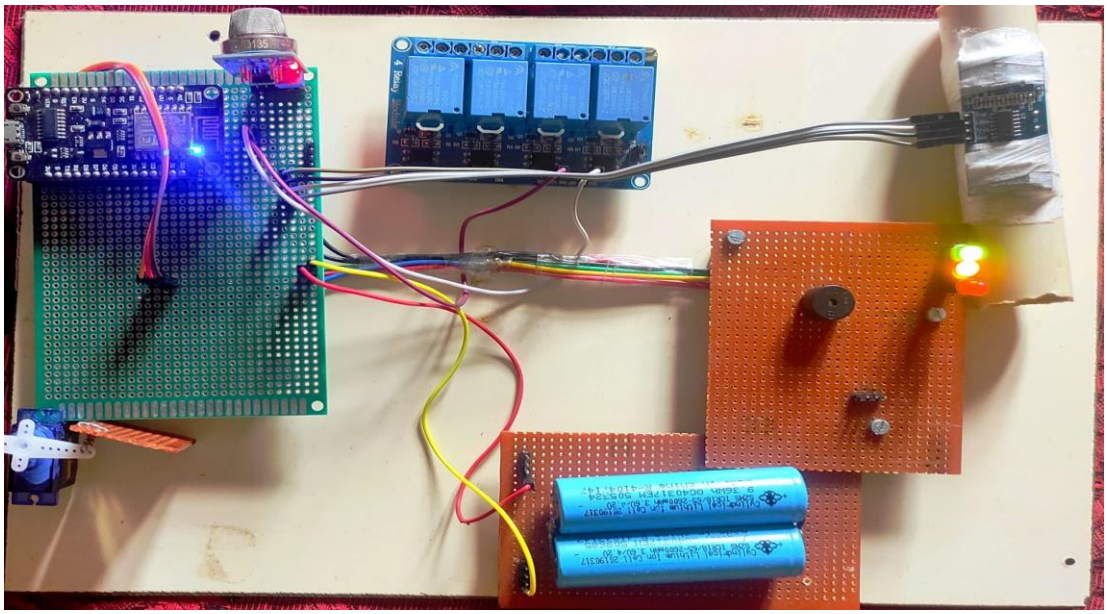

Fig. 4 Developed Working Model

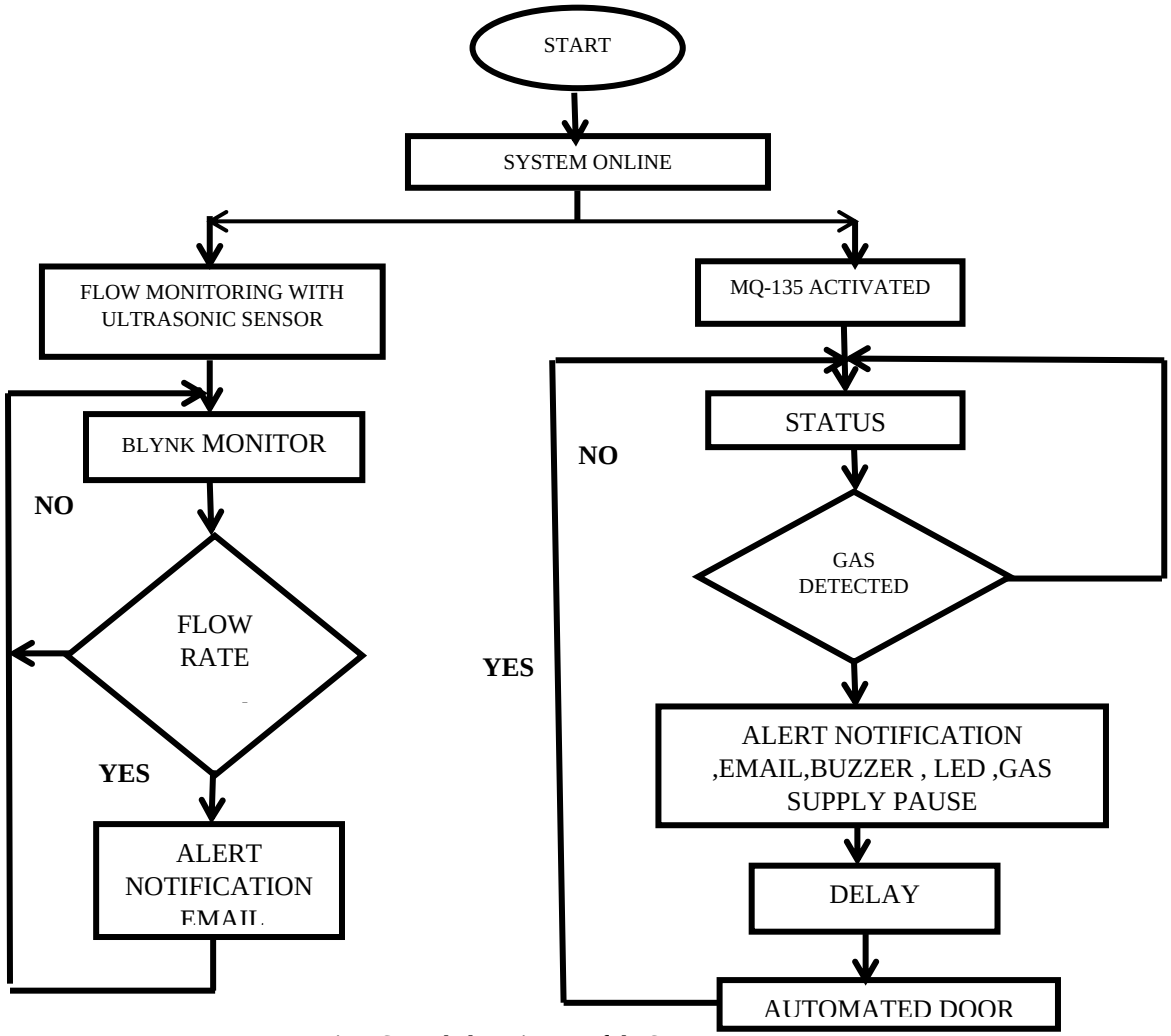

Fig. 5 Control Flow Diagram of the System

4. Results and Discussion

4.1. Monitoring

The monitored results are available live on the Blynk Platform. The graphical representation of these results makes it easier for Visualization and Analysis purposes. Based on the set threshold value of the ppm level of the gas in the pipeline, successive steps are carried out.

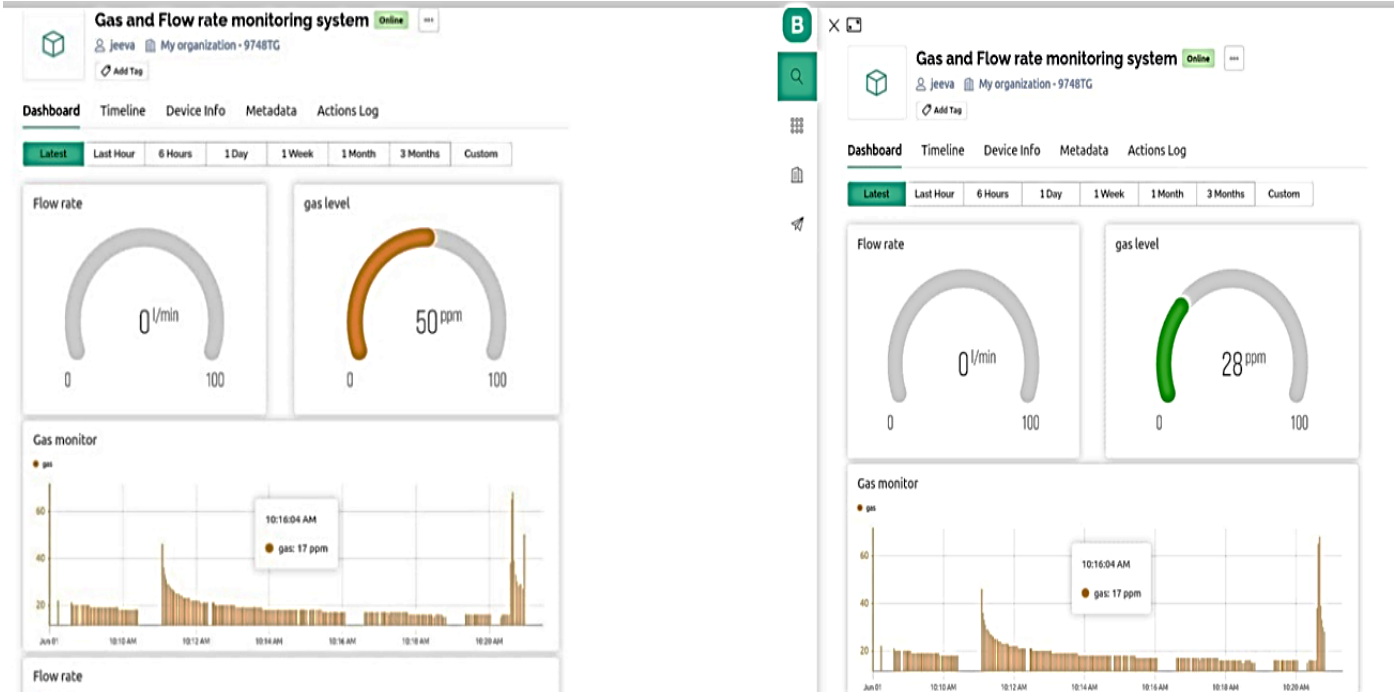

Fig. 6 PPM level 1 Graphical Representation of Live Flow Rate in ppm

4.2. Notifications

Notifications arise at two important stages when the system is in operation. First, when the system's flow goes above or below the threshold value. Second when any leakage is detected. First, a warning notification is generated on the Blynk Application itself. Then an E-mail notification is also sent.

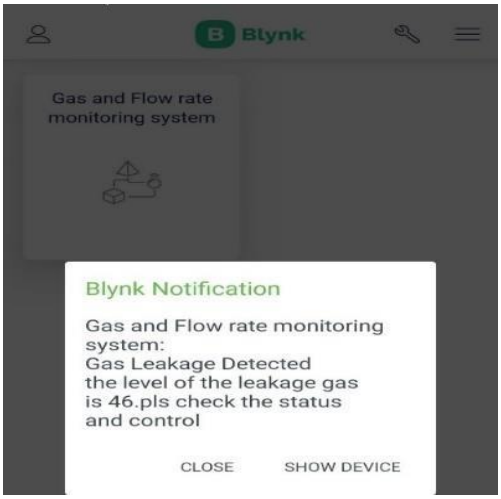

Fig. 7 Blynk Warning Notification

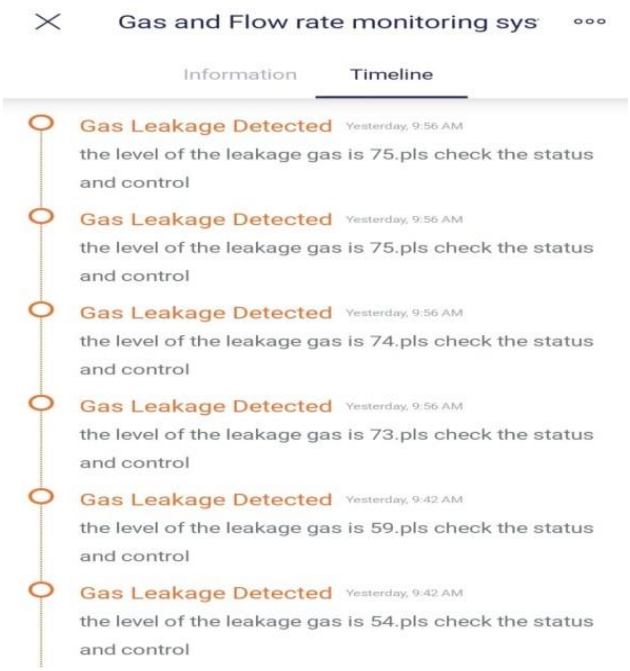

Fig. 8 Blynk Warning Notification

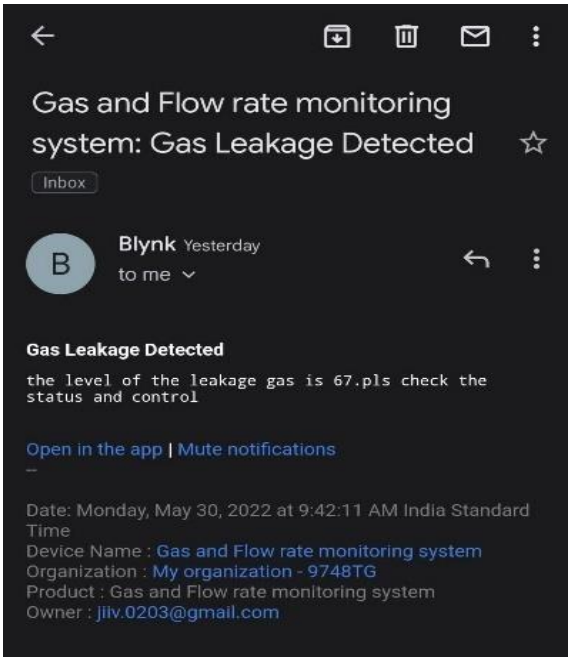

Fig. 9 Mail Notification

5. Conclusion

Thus an IoT - based smart control and monitoring system for industrial gas leakage problems is developed with the ability to monitor the pipelines, store the pressure levels and generate insights based on the data recorded. Thus, the system can monitor continuous data from the ultrasonic sensor and help us visualize using the Blynk Platform. The system works effectively with the sample gases used for testing. The performance of the sensors is greatly increased. The accuracy, time efficiency, and responses are the system's requirements. The smart monitoring and control system can encounter challenges in accuracy, speed, and effectiveness per its results. The results also meet the overall requirements with a low-cost design. The power of IoT and data have been showcased in this system. Beyond analysis and detection, automated alerting and emergency systems increase the level of safety in industries. The system only requires the change of sensors to make it function with distinct gases. The system can be made larger and advanced based on future needs and will take the AI path. The gas sensors can be easily replaced. To reduce power consumption.

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